The

Treatment of Burns

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WITH 199 ILLUSTRATIONS ON 105 FIGURES

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TO

Lucille Risley Artz

and

Louise Zibold Reiss

with affection

Preface

The literature on burns is vast. To the clinician who is called upon to treat severe burns only rarely it may prove more confusing than helpful He may experience difficulty in choosing from among the many apparently authoritative but conflicting viewpoints The chief purpose of this book is to furnish a guide for treatment in accordance with present day knowledge of burns. An ancillary purpose is to present information about certain practical details of management which are not discussed in scientific articles. These details often pose the most vexing problems in day to day patient care and at times, apparently trivial aspects of therapy may spell the difference between death and survival This book is not offered as an exhaustive treatise on burns. References to the literature are largely limited to particularly useful articles, but the text does take into account interpretation of information gained by various investigators throughout the world during the past two decades Although the techniques presented have seemed preferable to us, it is recognized that different methods may be beneficial in the hands of others

The burn wound evokes a systemic response reflected as a myriad of pathophysiologic processes Proper care of the burned patient requires the integration of many aspects of therapy such as fluid balance, wound management, anesthesia surgical technique, nutrition treatment of infection physiotherapy and psychotherapy It is in the burned patient that the science and the art of medicine meet Undue preoccupation with one or two facets at the expense of others may lead to disastrous consequences It should be recognized that the discussion of burns under various chapter headings introduces divisions that are convenient for the purpose of presentation but are misleading so far as the physician s clinical approach is concerned In the actual care of patients many problems require simultaneous consideration

For this reason, the book contains much purposeful repetition in addition to liberal cross references

Because of the complexity of the problem studies are more effectively carried out by a research team than by an individual In 1949 the Surgical Research Unit of the Brooke Army Medical Center began to develop such a team for the treatment and investigation of burns. In the seven years that followed more than one thousand burned patients were admitted for treatment and study to Ward 7 of the Brooke Army Hospital The bulk of the material presented in this book is a synthesis of the knowledge that has been gained from this experience. Various surgeons and investigators were assigned to the laboratory and to the ward of the Surgical Research Unit for two-year periods Each brought to the team a critical mind and knowledge from the disciplines of his past training The intelligent skepticism of new clinicians provided a means of testing and retesting the validity of various concepts and techniques This book outlines practices that have evolved from such an environment

CURTIS P ARTZ
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Acknowledgments

IT WAS largely due to the vision and pioneering efforts of Colonel William S Stone formerly chief of the Research and Development Division Office of the Surgeon General Department of the Army, that the organization of a burn unit was initiated Through the years his successor, Brigadier General John R Wood, and other members of the division Colonel Glenn J Collins and Major Charles C Pixley have given excellent support The guidance aid, encouragement and freedom for investigation provided by Major General William E. Shambora, Commanding General Brooke Army Medical Center made possible a fertile environment for research

We are deeply indebted to our former chief Lieutenant Colonel Edwin J Pulaski, the first director of the Surgical Research Unit under whose leadership the burn unit was established Great credit is due his successor Colonel William H Amspacher who gave much valuable guidance and assistance for organization and development of the investigative team

In the formative years the advice and inspiration from frequent visits of two great masters in burn surgery, the late Dr Everett I Evans and the late Dr Harvey S Allen, gave a firm foundation for sound clinical care and fruitful investigation Dr Francis D Moore and Dr Truman G Blocker civilian consultants to the Surgical Research Unit provided guidance stimulation and coordination with other research groups Dr Oliver Cope generously shared his vast clinical and investigative experience The influence of leaders in burn centers in other parts of the world was ever present by free interchange of ideas through visits and correspondence Chief among these were Mr A B Wallace of Edinburgh, Scotland, Dr Karl Erik Hogeman of Malmo Sweden and Mr Douglas M Jackson of Birmingham England.

It is a pleasure to acknowledge the assistance of many associates. Foremost among these is a former colleague Dr John H Davis, who would have been a coauthor had not the termination of his period of military service taken him away from the Surgical Research Unit His enthusiasm, untiring efforts and ideas were an integral part of the initial development of the investigative team. Many clinicians participated in the care of the patients and in the clinical studies. Their careful analyses of sections of the manuscript were most helpful Our deepest gratitude is extended to Drs Benjamin A Barnes Jerrold M Becker Alvin W Bronwell, William P Fite, Benjamin H Gaston Robert P Hummel N Carl Fredrik Liedberg, Bruce G MacMillan Paul Mandelstam John A Moncrief Robert D Pillsbury Yoshio Sako, Harry S Soroff and Jerry A Sturman

The section on anesthesia was reviewed by Dr Howard Pedigo Captain Elinor Pearson research dietician, participated extensively in the investigative studies as well as in the management of the patients Several chief ward nurses—Captain Mary Axman, Captain Edith Bonnet Major Betty Colyer Captain Margaret Maher, and Captain Olga Ricknell—were of invaluable assistance by providing splendid nursing care Mr Burr Bush contributed a very important part of the book by his precise and clear illustrations The photographs are a tribute to the ability of Mr Claude Dresser and his associate Mr John Tucker

We wish to thank the publishers of the following journals for their permission to reproduce various figures that have appeared in our previous articles American Journal of Surgery Annals of Surgery Archives of Surgery Journal of the American Medical Association Journal of Clinical Investigation Postgraduate Medicine Surgery Surgery Gynecology and Obstetrics and the J B Lippincott Company for figures in our chapter on Burns in their book *Surgery of Trauma* edited by Warner F Bowers

Special appreciation is due Miss Edith Royce, publications editor of the Surgical Research Unit for her painstaking editing of the manuscript and to our secretaries Miss Goldie Smith and Mrs Henry F Shaper Finally it is a pleasure to acknowledge valuable counsel and cooperation from the staff of the W B Saunders Company

THE AUTHORS

Contents

CHAPTER 1

The Scope of the Burn Problem

THE TREATMENT of burns is a problem both in civilian surgical practice and in military medicine. The magnitude of this problem is not widely appreciated It is the purpose of this chapter to convey a general view of various facets of the burn problem, to emphasize the needs of the present, to suggest a glimpse of the future, and to propose some partial solutions

BURNS IN CIVILIAN PRACTICE

In 1954 6 800 deaths occurred from burns in the United States [8] It has been estimated that 10 to 15 burned patients require hospitaliza tion for every burned patient who dies thus, a conservative estimate would be that approximately 70 000 burned patients are hospitalized every year According to Moyer s calculation, about 6 000 hospital beds are occupied the year round by burned patients [7] The cost of burns in terms of human suffering and loss of social usefulness is inestimable.

Causes of Burns

Inquiries by various investigators about the causes of burns have yielded essentially similar conclusions [3 4 7]

(1) At least half of all burning accidents could be prevented There are some who believe that with the exercise of reasonable caution and the introduction of well known safety measures, 70 to 80 per cent of all burns could be prevented

(2) Open fires and unprotected heating units are responsible for an unusually large number of burns This problem is of great im portance in Great Britain and in the American Southwest where un protected gas heating units are commonplace

(3) Ignition of clothing is a frequent mode of burning, particularly in young girls whose skirts are readily ignited by contact with fire In Bleck s analysis of 344 burned children ignition of clothing caused the burn in 46 per cent.[1]

(4) The home rather than the workshop is the place where burns are most likely to occur In Colebrook s series as well as in Moyer's 70 per cent of all burning accidents occurred around the home

(5) *Children are commonly the victims in burning accidents* In Colebrook s experience, 70 per cent of all burned patients admitted to the hospital were children those under the age of five being most often affected. In the United States the proportion of burned children is *somewhat smaller perhaps 30 to 50 per cent*

BURNS IN MILITARY MEDICINE

In warfare that does not involve the use of thermonuclear weapons burns are rare in comparison with other forms of serious trauma. Burns due to flame throwers are liable to be fatal instantaneously Phosphorus burns occur but not commonly Vesicant gases such as mustard gas, are a potential source of burns but they have not been used in recent wars

Many burns in military medical practice occur as a result of plane crashes Many of these injuries are fatal instantaneously Deep burns of the exposed portions of the body—the face and hands—are common If the clothes are ignited, very extensive and deep burns occur In addition to these patients whose injuries are a result of the hazards of military life there are many patients who are burned owing to simple carelessness in everyday activities such as in the handling of gasoline and the use of field stoves.

Much of what has been written about the problems of burns in atomic warfare is now outdated by the developments of weapons whose devastating capacity far exceeds that of the bombs delivered to Hiroshima and Nagasaki Information has not been released about the biologic effects of the newer weapons. There can be no doubt however that the problem of burns in thermonuclear warfare would assume proportions that stagger the imagination Not even the experts claim to have any concrete conception of the magnitude of this potential problem or any realistic ideas about possible solutions Anyone who has had experience in the concurrent management of as few as three seriously burned patients recognizes the overwhelming task of managing thousands or a hundred thousand burns Since despair is the useless reaction to great problems some fairly reasonable general approaches have been proposed from time to time (see Chapter 12)

TEACHING PROBLEMS

In general, there is no injury that is treated less expertly by the medical profession at large than a burn This is tragic in view of the extraordinary degree of suffering, financial loss and loss of social usefulness caused by the injudicious treatment of burns. Many patients with third-degree burns who could be healed within three or four weeks occupy hospital beds for months and even years Some patients who could be quickly rehabilitated by energetic therapy develop avoidable deformities that prevent them from working, others are unnecessarily disfigured and some actually die owing to neglect

It is clear that the teaching of burn therapy is not adequate at any level of medical education Although a senior medical student or an intern may not be expected to be expert in the art of skin grafting, he should be well grounded in the fundamental principles of therapy and capable of giving adequate emergency care General practitioners, internists and pediatricians must learn that the limitations of their particular interests demand the skill of the general or the plastic surgeon for the management of a third-degree burn Nonsurgical specialists may well treat second-degree burns but it is essential for them to recognize the characteristic features of the deeper injury The sooner the surgeon can treat the patient with third-degree burns the better for all concerned Transfer of responsibility to the surgeon several months after injury results in waste of time, money, and energy and in needless suffering

Unfortunately, many well trained surgeons may be incapable of properly managing a deep burn Too often surgeons shy away from taking responsibility for the care of burned patients during the period of residency training This is understandable, for the surgical resident is notoriously busy and the treatment of only a single severely burned patient is an extremely time-consuming task. Other factors that steer the resident away from burns are the burned patient s reputation for ingratitude, most surgeons preference for clean surgery and lack of encouragement from senior attending surgeons Some hospitals actually refuse to admit seriously burned patients Hospital administrators apparently recognize that few patients can afford the expense of prolonged therapy and, therefore, that the hospital bill may never be paid

There is an urgent need for improving the teaching of the therapy of burns Responsibility for effecting an improvement lies principally in the hands of the professors of surgery who exert a dominant influence in medical school as well as in postgraduate education Chiefs of surgical departments in hospitals not affiliated with universities must also share in this responsibility Awareness of a problem is

commonly the first step towards its solution The medical profession has demonstrated in the past that it is capable of prompt and effective action when it becomes cognizant of its deficiencies in certain respects.

IMPROVED ORGANIZATION FOR THE CARE OF BURNS

Burns may range from a very minor lesion to the most severe form of injury to which man is liable Obviously minor burns are easily managed, but the more severely burned patients require a specialized team of people for expert care Thus intelligent sorting is required a patient having a minor burn may be treated as an outpatient but the extensively burned patient should be referred to an institution where facilities and personnel are available for adequate management (see Chapter 2) There is an urgent need for the establishment of burn centers both civilian and military Burns like other difficult medical problems (poliomyelitis tuberculosis) are best treated in specialized institutions Although the building equipping and staffing of such centers would be quite expensive specialized institutions would afford the most economical and efficient method of managing severe burns Like many other severe disabling diseases burned patients should receive public support in order to allow for a diffusion of cost. There is a need for fund raising campaigns similar to those carried out for the study and treatment of acute poliomyelitis State rehabilitation programs and crippled childrens commissions should support the treatment of severe burns The staffs of many hospitals and teaching centers have the knowledge for expert burn care but ancillary help and organization is lacking because of the tremendous cost Since a trained specialized team is not available many costly compromises in therapy have to be made One of the greatest needs is proper financial support and organization for expert care of the patient with third-degree burns

THE CHANGING CHARACTER OF THE BURN PROBLEM

Physicians who have a special interest in the problem of burns are often approached with the question What is new in burns? The inquirer usually expects to learn about some magic lotion some miraculous dressing, or some foolproof formula Such questions are prompted by the excessive emphasis of the professional and lay press on certain interesting but really unessential aspects of therapy Fads and gadgets come and go without substantially altering the outlook for the burned patient. Nobody need fear that he is behind the times because he has not heard of the latest trick

Progress in the treatment of burns has been slow but steady during the past 20 years Improved understanding of certain physiopathologic

mechanisms quite naturally suggest new approaches in therapy Studies in the early shifts of protein, water, and electrolytes have resulted in vastly improved management in the early postburn phase Modern fluid therapy has decreased the mortality in moderate burns and prolonged the survival time in extensive burns The extraordinary progress made in fluid therapy has created new problems, since patients who formerly died from fluid deficits now live long enough that their survival is threatened by other factors Thus the unusual situation has arisen where striking advances in one aspect of management appear to have created new problems

The introduction of potent antibiotics has brought about a dramatic change in the importance of various types of infections in burns Sepsis caused by Group A beta hemolytic streptococci which posed very great difficulties in the presulfonamide era, can now be combatted readily, but the invasive infection by other microorganisms has become an ever greater threat to the seriously burned patient

The principles of therapy of third-degree burns have been well known for a long time Eschars represent dead tissue, proper therapy demands removal of the dead tissue and its replacement by living tissue. Nothing could be more simple in principle yet more difficult in actual practice Important changes have occurred in the attitude of surgeons toward the best methods of achieving the removal of eschar and important changes may be expected in the near future

APPRAISAL OF PRESENT DAY PROBLEMS

Fluid Therapy

Despite differences in detail, several methods of management based on current understanding of fluid shifts have yielded good results Startling departures from the now customary therapeutic approaches are not expected in the near future However, much remains to be learned both in respect to basic physiologic alterations and details of therapy

Increasing emphasis may be expected on the problem of fluid therapy after 48 hours In the past, it was assumed that fluid problems cease to exist when wound edema becomes maximal The fallacy of this assumption has become evident in recent clinical experiences and experimental studies.[6]

Infection

The control of invasive infection is becoming an increasingly vexing problem in the therapy of burns It is clear that even the potent antibiotics now available have failed to solve the problem There is practically no information concerning the effect of burning on the

body's capacity to resist invasive infection. An extensive study of burns by immunochemical means is badly needed The problems of infection are interwoven inseparably with those of eschar removal and homografting.

Removal of Eschars

Some progress has been made in the removal of eschars, but present methods remain far from ideal Much has been learned about the extent of eschar that permits safe excision technical aspects of excision, and proper timing. Severely burned patients often cannot tolerate the stress of an extensive excision and, at times excision induces septicemia by an overwhelmingly large number of microorganisms Enzymatic removal of eschars is still in the experimental stages

Homografting

The clinical concepts and experiences in the use of homografts by Brown and his associates have proved most valuable [2] Useful data are available on the indications for homografting, practical techniques for obtaining the grafts storage of grafts, and the expected length of survival of the grafts Unfortunately the application of homografts depends on the prior removal of eschars, and the grafts often fail to survive for a sufficient period. The problem of homograft survival is of the utmost importance It is being extensively studied by basic scientists throughout the world A recent report on the apparently permanent survival of the skin homograft in a patient with agammaglobulinemia is of great interest because it strengthens the view that the failure of grafts to survive is related to an antibody-antigen reaction [5]

If invasive infection could be prevented by the expeditious removal of eschars and if permanently surviving homografts could then be applied survival of even the most severely burned patient would be conceivable

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CHAPTER 2

General Immediate Care

THE TREATMENT of a small, partial thickness burn is a rather minor procedure for complete healing occurs without scarring if the area is kept clean The management of an extensive burn—one of the most complex illnesses to which man is liable—requires the utmost in professional skill and care It involves the understanding of surgical techniques respiratory physiology, marked physiologic changes in electrolyte and fluid balance nutrition bacteriology and psychiatry A knowledge of almost every principle taught in surgery is required for the treatment of the severe burn

FIRST AID

The chief aim in rescue is to smother the fire and not to fan it A person whose clothes are on fire should not run since running fans the flames He should not remain standing since this position may cause him to inhale flames or cause the hair to be ignited Burned persons must be placed first in a horizontal position and then rolled in a blanket or a rug to smother the flames. Even coats or other garments may be used for this purpose If no covering material is available a burned person should lie down and roll over slowly Water or noninflammable liquids are of obvious value Dirt and sand should not be used unless nothing else is available

The initial step in the care of a burned patient is to cover the burn wound in order to prevent contamination and to alleviate pain by preventing air from coming in contact with the injured surface The patient should then be transported to a physician s office or hospital Medicaments or home remedies should not be applied A clean sheet or cloth may be used as an emergency dressing.

Stimulants must not be used A patient is usually frightened and he needs to be reassured Oral intake must be avoided

Chemical burns caused by acid or alkali should be washed immediately with copious quantities of water in order to get rid of the injurious agent All clothing must be removed. If a large quantity of a chemical burning agent has come in contact with the skin the patient should get in a bathtub or under a shower

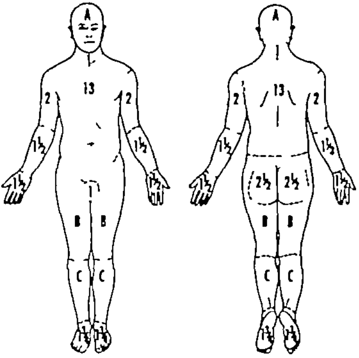
APPRAISAL OF THE SERIOUSNESS OF A BURN INJURY

It is difficult to make an accurate appraisal of the relative magnitude of different types of mechanical injuries On the other hand the severity of the burn injury can be assessed quite satisfactorily since it depends on only two principal factors—percentage of body surface burned and depth of burn. Additional factors that determine the seriousness of a burn include its location the age and physical condition of the patient, and the presence of concomitant injury

Estimate of Percentage of Body Surface Burned

The extent of a burn is usually expressed as a percentage of the total area of body surface injury In 1924 Berkow presented data concerning percentage of surface areas of various parts of the body [2] Lund and Browder found that Berkow s tables were not applicable to all ages They determined the changes in percentage of body surface of various parts that occur during different stages of development from infancy through childhood [4] The area of the head makes up a relatively large proportion of the total skin area of infants as compared with the findings in adults This disproportion is counterbalanced in infants by the smaller proportionate area of the thighs and legs The proportion of skin of all other parts is essentially the same at all ages (Table 1)

The most accurate method for determining percentage of body surface burned is to map out the areas of injury on Lund and Browder charts (Fig. 1) If these charts are not immediately available for an initial estimate a rapid method of estimating percentage of body surface burned is the use of the Rule of Nines Information obtained by this simplified rule is sufficiently accurate for clinical purposes. According to the Rule of Nines first devised by E. J Pulaski and C W Tennison, the body surface is divided into areas representing 9 per cent or multiples of 9 per cent the head and neck 9 per cent anterior trunk 2 x 9 or 18 per cent, posterior trunk 18 per cent, each lower extremity 18 per cent each upper extremity 9 per cent and the perineum 1 per cent (Fig 2) [5] The Rule of Nines has been widely



Relative Percentage of Areas Affected by Growth

Age	Age in Years					
	0	1	5	10	15	Adult
A—½ of head	9½	8½	6½	5½	4½	3½
B—½ of one thigh	2¾	3¼	4	4¼	4½	4¾
C—½ of one leg	2½	2½	2¾	3	3¼	3½

FIG 1 Lund and Browder charts. These charts permit a rather accurate method for determining percentage of body surface involved.

Table 1 Contribution of Various Body Areas to Total Body Surface at Different Ages, by Per Cent*

AREA	BIRTH 1 YR.	1–4 YEARS	5–9 YEARS	10–16 YEARS	15 YEARS	ADULTS
Head	19	17	13	11	9	7
Neck	2	2	2	2	2	2
Anterior trunk	13	13	13	13	13	13
Posterior trunk	13	13	13	13	13	13
Buttocks	5	5	5	5	5	5
Genitalia	1	1	1	1	1	1
Upper arms	8	8	8	8	8	8
Forearms	6	6	6	6	6	6
Hands	5	5	5	5	5	5
Thighs	11	13	16	17	18	19
Legs	10	10	11	12	13	14
Feet	7	7	7	7	7	7

*Adapted from Lund and Browder[4]

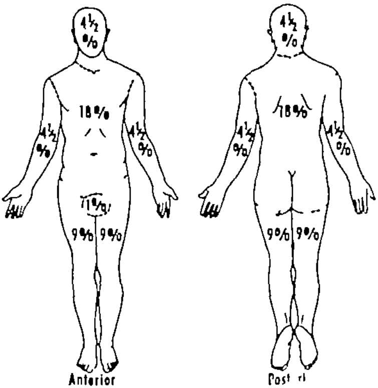


Fig 2 Rule of Nines A rapid method of estimating percentage of body surface involved

accepted as a useful guide in estimating percentage of body surface burned

The extent of a burn is only rarely underestimated Overestimation is common and frequently causes excessive fluid administration (see Chapter 3)

Depth of Burn

Although the most experienced observers are often mistaken in their initial judgment of the depth of a burn in a particular area, a fairly accurate over-all estimate of the predominance of one or the other type of injury can be made in most cases (see Chapter 4)

Since the systemic derangements and prognosis are directly related to the amount of tissue destroyed, it is obvious that a full thickness burn is more serious than a second-degree burn of similar extent It is difficult to assess the exact relation of severity of second-degree burn to third-degree burn Bull and Squire reviewed the case records of 794 patients treated during the years 1945 through 1947 at the Birmingham Accident Hospital in Birmingham England The trend of mortality was found to be best expressed in terms of third-degree burn plus one-quarter of the second-degree burn Thus area for area a deep burn seemed to be four times as serious as a superficial burn [3]

In a recent study of 323 burned patients who were hospitalized at

Brooke Army Medical Center, Schwartz and co-workers showed that the best correlation between case fatality rate and survival time was obtained when the percentage for second-degree injury was given one half the weight, area for area of the percentage of third-degree injury A burn index was suggested based on assessment of one point for each per cent of third-degree injury and one half point for each per cent of second-degree injury In a mixed burn of 20 per cent second degree and 20 per cent third-degree involvement, the index is 20 plus one-half of 20 or a total of 30 This simple index serves as a practical guide for severity of injury [6] Such a refinement may be of value in comparing well documented cases It must be remembered however, that the exact diagnosis of burn depth is often difficult and that it is subject to revision during the healing stages

Site of Burn

In some parts of the body burns are followed by such crippling deformities that they must be regarded as serious even though they are of small extent. These areas of functional importance are the face hands feet, external genitalia and flexion creases. If a burn is complicated by a fracture or soft tissue injury there is a greater threat to survival and the difficulties of treatment are greatly increased Burns of the respiratory tract are particularly serious regardless of the amount of surface area involved

Age and Physical Condition of the Patient

A burn is considerably more serious in a very young infant or an elderly person Patients who have renal cardiovascular or pulmonary diseases cannot tolerate burns of even minor extent. Thus age and general physical condition of a patient prior to the burning accident may contribute to the seriousness of the injury

DISPOSITION OF BURNED PATIENTS

Any physician who is called upon to treat an open fracture of the femur is aware of the immediate necessity of general supportive care of the patient and transportation to a well-equipped hospital where an experienced staff can care for such an injury Similar management is required for a severe burn All too often a physician who sees a patient having a burn of 25 per cent of the body surface feels that he can take care of the patient until it is time for grafting and then refer him to a plastic surgeon This postponed referral is deplorable Inadequate management during the initial period is followed by infection chronic anemia weight loss wounds that are not debrided and heaping granu

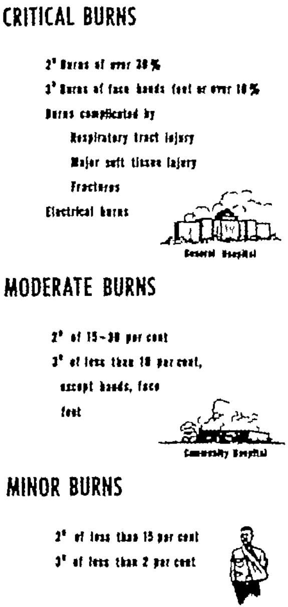


FIG. 3 An outline for sorting or disposition of burned patients.

lations As a result, when the patient is referred to the plastic surgeon he is frightened, in chronic pain, and demoralized

It is extremely important to realize that disposition of a burned patient depends on the appraisal of the severity of injury[1] Three groups of patients may be distinguished (1) critical burns, that must be referred to a well-equipped general hospital where there is a surgeon experienced in burn care, (2) moderate burns, that may be treated in a small community hospital and (3) minor burns, that may be treated on an outpatient basis (Fig. 3)

Critical Burns

These include (1) burns complicated by respiratory tract injury (2) partial thickness burns of more than 30 per cent of the body

surface, (3) full thickness burns of the face hands feet genitalia or of more than 10 per cent of the body surface, (4) burns complicated by fractures or major soft tissue injury (5) electrical burns and (6) deep acid burns In addition the age and the general physical condition of the patient may indicate that burns of smaller extent should be considered as critical In all of these cases a patient must be sent promptly to an institution where proper treatment can be given

Moderate Burns

These include (1) partial thickness burns of 15 to 30 per cent of the body surface and (2) full thickness burns of less than 10 per cent of the body surface providing the hands face feet or genitalia are not involved

Minor Burns

These include (1) partial thickness burns of less than 15 per cent of the body surface, and (2) full thickness burns of less than 2 per cent of the body surface that may be treated on an outpatient basis until the patient needs to be hospitalized for minor grafting Small burns in children may be treated in a small community hospital for a few days until the patient s condition becomes stabilized The child may then be sent home if the family can provide intelligent care

Transportation of Burned Patients

If transportation to a hospital requires less than half an hour the only treatment required is a small dose of morphine intravenously However if transportation is expected to require more than half an hour the attending physician should initiate fluid therapy with a plasma volume expander such as dextran or with lactated Ringer s solution

Patients may be transported several hundred miles by air during the first 24 hours following a burn providing fluid and electrolyte requirements are fulfilled in transit Experiences in the movement of recently burned patients prove that physiologic derangements grow progressively worse after injury Therefore the patient does not tolerate prolonged transportation as well after 48 hours as he does before that time In critical burns a medical escort is essential Before transport is begun, a cannula should be well anchored in a vein and the adequacy of the airway must be assured In burns of the face and tracheobronchial tree it may be wise to perform a tracheotomy before attempting prolonged transportation

It is a common misconception to think that a recently burned patient is too sick to be moved In fact his chances for survival are much

better if he is transported early to an institution having the necessary facilities and trained personnel for definitive care

INITIAL HOSPITAL PROCEDURES

A patient's clothing should be removed as soon as he is admitted to the hospital A brief history of how the burn was incurred the possibility of other types of injury and general status prior to the accident are important for an over all evaluation of the patient s general condition It is advantageous to weigh the patient as soon as his clothes are removed and before putting him in bed This gives a base line for fluid therapy which must be initiated immediately

The initial steps in care must be planned carefully If two or more physicians can attend the patient, the procedures may be carried out with greater dispatch by one physician planning and directing and the other carrying out the technical procedures As the history is being taken a physician can alleviate some of the patient s worries by reassuring him Initial procedures are minimal in minor and moderate burns since fluid replacement therapy is given by the oral route, however in burns covering more than 20 per cent of the body surface, several procedures are imperative (Table 2)

Table 2. Outline of Immediate Hospital Procedures

1 Obtain history over-all estimate of burn, and weight of patient
2. Determine need for tracheotomy
3 Reassure patient and give intravenous morphine, if necessary
4 Draw blood for laboratory determinations cross-match start fluids
5 Insert cut-down cannula or femoral cannula
6. Insert indwelling urinary catheter
7 Plan therapy—from weight and per cent of burn
   estimate amounts needed of blood and other colloids, sodium solutions, water
8. Give antibiotics—penicillin and streptomycin
9 Give tetanus prophylaxis—toxoid or antitoxin
10 Initiate local care cleansing, dressings or exposure
11 Make a worksheet-type of chart

Sedation

Even though pain is not a prominent feature of extensive deep burns a small dose of morphine is beneficial when given intravenously Morphine eliminates apprehension, makes the patient more comfortable and alleviates the pain connected with cleansing the burn wound It cannot be overemphasized that sedation in burns must be given intravenously If a narcotic is given subcutaneously it is not usually absorbed until the circulatory deficiency is corrected All too often patients receive morphine subcutaneously and the drug gives no particular relief As the result, a second and larger dose is given sub-

cutaneously but again without a beneficial effect After replacement therapy has been carried out the large load of morphine that has been deposited in the subcutaneous tissue is absorbed and the patient s vital functions are depressed Breathing becomes slow and the patient may become cyanotic

In adults a dose of 8 to 10 mg. of morphine is usually adequate A small dose of codeine or morphine may be used for children A good rule of thumb for dosage of morphine in children is 1 mg. for each 10 pounds of body weight The morphine should be diluted in 3 to 5 cc. of saline and injected intravenously over a period of 1 or 2 minutes.

After the first 24 hours a narcotic may not be necessary for seda tion A short-acting barbiturate is frequently satisfactory to allay apprehension and to provide rest Two or three small doses of a nar cotic during the first 24 hours are not toxic and frequently make the patient more comfortable Extensively burned patients may have con siderable discomfort, and a few doses of a narcotic may be required every day for the first week. Large and frequent doses of a narcotic should be avoided, but an adequate amount of the medication should be used to assure the patient s comfort

Extreme restlessness is not an indication for a narcotic Hypovolemia is the most common cause of restlessness and disorientation in the acutely burned patient If the patient is in peripheral circulatory collapse, cerebral anoxia leads to extreme uncooperativeness and even mania It is not uncommon to see an uncontrollable patient become quite docile and cooperative as soon as the hypovolemia is corrected by the infusion of one or two units of a colloid solution

A burned patient should be placed in a room where the tempera ture is between 70 and 75° F In cooler rooms, he may feel chilly and uncomfortable

Tracheotomy

As soon as the physician sees a burned patient, he should decide whether or not a tracheotomy is necessary A tracheotomy must be performed whenever respiratory damage is suspected The presence of established respiratory difficulty may be diagnosed by hoarseness coughing, rapid respirations or cyanosis. Physical signs in the chest, such as rhonchi and rales, may or may not be present A history of being burned in a closed space or the appearance of redness in the posterior pharynx may suggest a diagnosis of respiratory damage A tracheotomy should be performed if there is a burn of the face and neck complicated by symptoms of respiratory difficulty Usually this procedure can be postponed until pain has been alleviated and re

placement therapy has been initiated Indications for tracheotomy in burned patients after the emergency period are discussed in Chapter 6

Establishment of an Intravenous Life Line

All patients with burns of more than 20 per cent of the body surface should have some type of intravenous cannula tied securely in a vein for the administration of fluid Immediately after a patient is admitted, blood is drawn with a large needle for crossmatching and routine laboratory determinations The initial electrolyte and colloid infusion may be given through the same needle

A venous life line is essential A large bore needle, well anchored in a vein is insufficient for early fluid therapy in severe burns Patients are often restless and displace apparently well anchored needles Repeated venipunctures then become necessary during the first few days Intravenous fluids may have to be used over a long period of time and blood transfusions are usually required for weeks or months There are not many veins suitable for the administration of intravenous fluids in extensively burned patients Gentle care of veins is therefore essential and veins must not be thrombosed or rendered inaccessible by hematomas in the early therapy In addition, there is often an excessive delay between the time when subcutaneous infiltration of fluids is noted and the time when a repeat venipuncture is performed, especially if infiltration occurs at night During the delay, marked fluid deficits may accrue

For these reasons an intravenous cannula is absolutely essential for optimal therapy The sites elected for a cut-down are the long saphenous vein on the medial aspect of the ankle, the brachial vein in the antecubital region and the brachial vein over the deltoid muscle The polyethylene catheter is threaded into the vein for a distance of several centimeters The catheter must be anchored securely by silk ligatures Because the solutions used for sterilizing polyethylene catheters are irritating to the intima of the vein great care must be taken in washing the wall and rinsing the lumen of the catheter with copious quantities of saline before it is inserted In general the largest catheter that will fit comfortably into a vein is used, usually one that can be connected with a 15-gauge or 18-gauge needle

After a catheter is tied in place, venous spasm may occur and retard the rate of fluid flow Under such circumstances 2 cc of a 1 per cent procaine solution may be injected into the catheter Injection of 1 cc of 1 per cent aqueous heparin solution into the catheter at intervals of 4 to 6 hours is helpful This amount of heparin does not affect the coagulation mechanism significantly but it does appear to have a beneficial effect in preventing thrombosis at the tip of the catheter

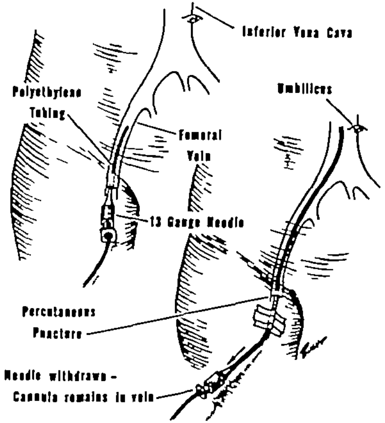


FIG 4 Diagram for technique of insertion of femoral cannula. The femoral vein is located just medial to the pulsation of the femoral artery below the inguinal ligament. A 13-gauge or a thin-walled 15-gauge needle is inserted into the vein. As soon as there is a free flow of blood, a measured segment of polyethylene tubing is passed through the needle into the inferior vena cava. The needle is then removed, leaving the tubing in the vein.

In some instances it is difficult to find a suitable vein for the insertion of a cut-down cannula In such cases a femoral cannula is most beneficial A 13 gauge or thin walled 15 gauge needle is inserted into the femoral vein and a measured segment of polyethylene tubing is threaded through the needle into the inferior vena cava The needle is removed and the tubing is allowed to remain in the vein (Fig. 4) Every four hours 1 cc of a 1 per cent aqueous heparin solution is injected in the cannula to prevent clotting at the tip The tubing must not remain in place longer than seven to ten days because of the dangers of thrombosis and pulmonary embolism The physician must be careful to measure the segment of tubing before it is inserted and again after it is removed This procedure prevents a portion of the tubing from being lost in the vein in case it should break off

Insertion of Urinary Catheter

In all burns involving more than 20 per cent of the body surface an indwelling catheter must be inserted into the bladder This provides

the only reliable method for measuring urinary output—a provision essential to the determination of adequate initial fluid therapy The catheter is irrigated with saline or 0.25 per cent acetic acid solution every 6 hours and changed at least once each week. It should be re moved as soon as it is not needed Urinary tract infections and peri-urethral abscesses are not uncommon when catheters remain in the bladder for prolonged periods of time

Antibiotic Coverage

No form of local care affords foolproof protection against in fection Routine antibiotic therapy is indicated Prophylactic therapy is initiated as soon as possible, preferably by the intravenous route Many antibiotics and various dosage schedules may be satisfactory A combination of one million units of penicillin and 0 5 gram of streptomycin intravenously every 12 hours can be recommended for routine purposes. This dosage schedule is followed until intravenous therapy is discontinued. For the first five or six days thereafter 600,000 units of procaine penicillin and 0 5 gram of streptomycin are given intramuscularly twice a day If there is inadequate control of infection, a broad spectrum antibiotic must be given The selection of the broad spectrum antibiotic depends upon the sensitivity of the bacteria that colonize the burn wound (see Chapter 7)

Tetanus Prophylaxis

Anaerobic microbes frequently colonize the surface of a deep burn Clinical tetanus has been reported in burns For this reason, routine tetanus prophylaxis must be given To individuals who have been immunized previously with tetanus toxoid, 0 5 cc of tetanus toxoid acts as an adequate booster dose If the period since the last injection of toxoid is more than four years, the prophylactic ad ministered should be antitoxin In addition 0 5 cc of toxoid may be given In inadequately immunized patients and those not previously immunized, 3 000 units of tetanus antitoxin should be given subcutaneously after testing the patient for sensitivity

Planning Replacement Therapy

As soon as the initial procedures are carried out a more thorough history is taken A rather careful estimate of the percentage of body surface burned should be made and a tentative plan outlined for the amount of replacement therapy Factors considered in estimating fluid requirements are extent of the burn depth of the burn age and general condition of the patient (see Chapter 3) Vitamin C (1 000 to

2,000 mg) and generous quantities of all other vitamins are ad ministered intravenously for the first two or three days (see Chapter 8)

Local Care

As soon as adequate replacement therapy has been assured, local care of the burn wound is initiated (see Chapter 4) During the initial phases of management of the burned patient all attendants should wear masks to prevent further contamination of the burned surface

Accessory Initial Procedures

Burned patients are usually quite thirsty and demand large quan tities of water In moderate burns, most of the replacement therapy may be carried out by the oral route. In more extensive burns para lytic ileus and vomiting are quite common during the first few days In an extensively burned patient all fluids are withheld and the entire replacement therapy is carried out by the intravenous route In some patients it may be necessary to insert an indwelling nasogastric tube in order to alleviate gastric distention dilatation or vomiting Gastric dilatation is a frequently unrecognized complication in an acutely burned patient

A patient usually fears disfigurement and prolonged disability Verbal reassurance can do much to alleviate this anxiety A family will also be more cooperative if they are given an honest appraisal of the patient s condition as well as a clear explanation of the procedures required, and the events anticipated in the management of an extensive burn Sympathetic explanations help to establish the patient s and the family s confidence in the physician Implicit confidence is really es sential because many uncomfortable procedures must be performed during the prolonged treatment and convalescence

The initial impression created by the hospital staff is a lasting one in the minds of patients. Every effort must be directed toward making the patient feel that he is cared for by individuals who are genuinely interested in him. Relatives are also most apprehensive A courteous and friendly attitude towards them may win their co-operation in the general management of the patient

After the initial procedures have been carried out a complete chart should be prepared In the case of extensive burns, a compre hensive chart will include detailed information needed in order to determine the exact status of a patient at all times (Figs 5 and 6) Plans must include provisions for observing the patient on an hourly basis for the first 24 to 48 hours

NAME					DATE			WEIGHT			
	INTAKE						OUTPUT				
		I V		ORAL							
TIME	FLUIDS	TIME ABSORBED	AMOUNT	TIME	AMOUNT	TIME	URINE	EMESIS	BP	TPR	LABORATORY
		TOTAL I V		TOTAL ORAL		TOTAL OUTPUT					

Fig 5 Sample bedside chart for initial period in severe burns.

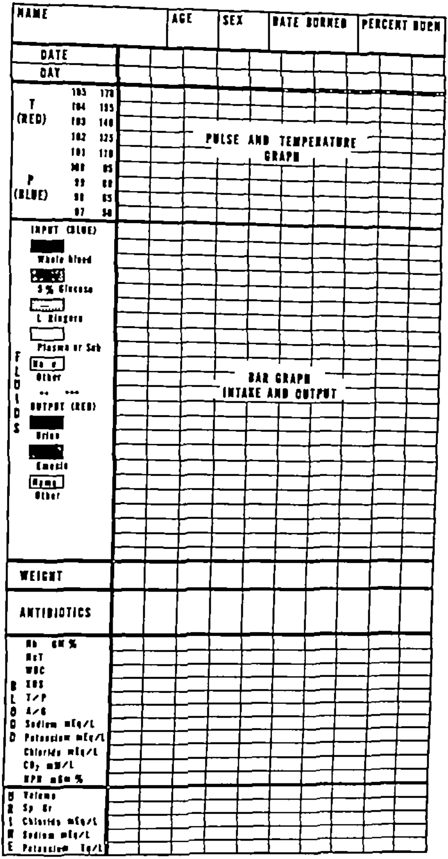


Fig 6. Sample day-to-day chart for the physician. This type of graphic display of information makes all important data available at a glance.

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CHAPTER 3

Initial Replacement Therapy

PROGRESS in the therapy of burns has been particularly impressive with respect to initial fluid therapy By the beginning of this century the beneficial effects of systemic fluid therapy were well recognized by some surgeons As a result of the painstaking investigations of Davidson and of Underhill saline therapy became standard treatment in the early 1930's[7, 23] The studies of Blalock gave impetus to the use of plasma[2] Harkins's simple and useful formula according to which the amount of plasma to be administered was determined by the degree of hemoconcentration gained wide acceptance in the early 1940's.[13] In 1947 Cope and Moore described a surface area formula and introduced the fundamentally important concept that the fluid losses are determined largely by the extent of burn[5] In 1952, Evans proposed a formula for estimation of fluid needs, taking into consideration weight of the patient as well as extent of burn[9]

Under ideal conditions in a well staffed well equipped hospital most extensively burned patients can be kept alive for two or three days if currently accepted methods of fluid therapy are used However successful management of the patient through the early period of rapid shifts of water electrolytes and proteins by no means assures ultimate survival Even though over-all statistics may not show an impressive reduction in the mortality of severely burned patients during the last decade the occurrence of death at a later time in the post burn course attests to the efficacy of modern fluid regimens.[15] Much remains to be learned about replacement therapy but appreciable reduction in mortality awaits progress in phases of treatment other than the early fluid replacement

PATHOLOGIC PHYSIOLOGY

Causes of Edema

Edema is an inevitable sequel of burning. The two fundamental factors involved in its production are vasodilatation and increased capillary permeability to proteins (Fig. 7) Both are a direct result of capillary injury caused by heat A third and as yet poorly understood factor concerns changes in the permeability of tissue cells in and around a burned area which may allow abnormal interchange of water and electrolytes between the cells and the interstitial fluid

Vasodilatation results in an increased capillary hydrostatic pressure The shift of plasma proteins into the interstitial spaces of burned tissues lowers the effective oncotic pressure of the plasma, edema is the result of this combination of changes The formation of edema is limited primarily by tissue tension As more and more fluid accumulates in the interstitial spaces tissue pressure increases. This is an important factor opposing further extravasation of fluid.

The Burn Wound

Although it is customary to think of a burn as a two-dimensional wound, i e a wound involving surface area rather than volume, a burn is a wound of three dimensions The area concept is quite naturally suggested by the appearance of the burn wound Depth of tissue injury, which is the third dimension is difficult to visualize and cannot be measured accurately Nevertheless, depth of burn is an extremely important factor affecting the volume as well as the composition of fluid losses from the circulation In a first-degree burn, vasodilatation is the only change that occurs Protein losses are insignificant and edema is barely perceptible A second-degree burn is characterized not only by more severe capillary damage but also by damage involving a larger volume* of tissue than a first degree burn of the same extent

While the area burned is readily gauged by inspection of the wound the volume of tissue in which capillaries are functionally deranged is not immediately evident A large amount of fluid can accumulate beneath the surface of the wound before any visible swelling occurs. Leakage of proteins is observed in areas that receive the most heat, while only hyperemia occurs in areas subjected to less heat

In third-degree burns the entire thickness of the skin is destroyed Capillaries are thrombosed close to the surface of the wound This has a twofold effect erythrocytes are removed from the circulation and

* It would be more accurate to speak of the mass of functionally injured tissue. In order to emphasize the three dimensional character of a burn wound however the discussion points out the concept of volume in contradistinction to area.

SEQUENCE OF EVENTS RESULTING IN BURN SHOCK

HEAT

Increased capillary permeability

Vasodilatation

Increased capillary hydrostatic pressure

Leakage of plasma proteins into interstitial fluid

Rapid loss of H_2O and salt

Decreased effective oncotic pressure of capillary blood

Increase in plasma proteins in general circulation

Edema

Water and salt moves from unburned tissues into circulating blood

Decreased blood volume

Circulatory collapse

Compensation adequate

FIG. 7 Diagrammatic outline of burn shock

fluid exchange ceases. The former contributes to the development o anemia while the latter explains the curious fact that fluid losses do not originate in the most severely injured tissues It has been shown that there is no exhange of water and electrolytes in the eschar of a third-degree burn The extensive fluid loss caused by a third-degree burn appears to be due to injury of a large volume of tissue beneath and surrounding the area of full thickness skin destruction The deeper the burn, the greater the fluid loss

The type of tissue involved is important. Injury to relatively avascular subcutaneous tissue causes less loss of fluids than injury extending into highly vascular muscle tissue To a lesser extent, the location of the injury is of some importance when the fluid losses are considered in burns of the same extent and depth Burns of highly vascularized areas, such as the face are generally believed to cause greater losses of fluids than comparable burns in other locations (Fig. 8)

Contrary to general belief, the visible fluid losses at the surface of a second-degree burn constitute only a small fraction of the total amount of fluid that is functionally lost The greatest fluid losses occur deep in the wound. Even more misleading are the changes that occur in third-degree burns which are characterized by a dry surface and a small amount of visible swelling In such burns, the firm eschar prevents obvious swelling but large volumes of fluid extravasate into the deeper tissues From a clinical point of view it is extremely difficult to achieve a correlation between the amount of fluid lost into an injured area and visible formation of edema Large quantities of fluid may accumulate in deeply located tissues without any evidence of swelling. In both second-degree and third-degree burns, relatively small changes in a measurable parameter, such as the circumference of a limb may be associated with a surprisingly large fluid accumulation (Fig 9)

Volume and Rate of Fluid Losses

The volume of fluid lost into the tissues cannot be accurately measured in man Experimental work on animals as well as clinical studies indicate that the extent of burn is probably the most important factor influencing the magnitude of fluid losses

In the treatment of burned patients there is a good correlation between the extent of burn and the volume of fluid therapy required to prevent circulatory collapse However the exact functional relationship between the extent of burn and fluid requirements cannot be established by clinical information One reason for different estimates of fluid needs by various observers is the wide range between the

FIG. 8. *A* Appearance of the face three hours after the patient sustained a deep dermal burn of the face. *B* Eight hours after injury *C* Twenty-four hours after injury A tracheotomy was performed to assure adequate clearance of tracheobronchial secretions. *D* Forty-eight hours after burning. Edema is now maximal. *E*. Healing is complete after 40 days.

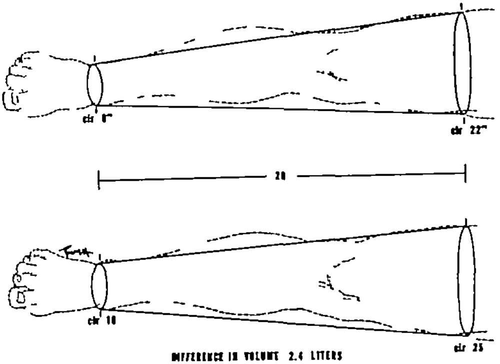

FIG 9 Relatively small changes in the measurable parameter such as the circumference of an extremity may be associated with large fluid accumulations. A lower extremity is here considered as the frustrum of a cone with an upper circumference of 22 inches and a lower circumference of 9 inches. A change of 3 inches in the upper circumference and a change of 1 inch in the lower circumference would result in a volume change of 2.4 liters.

volume of fluid given that will sustain physiologic balance and the volume of fluid therapy that may be excessive Furthermore there is some difference of opinion as to what constitutes a physiologic balance

Despite the lack of uniformity in management, there is a general agreement about the linear relationship between extent of burn and fluid requirements The differences of opinion are chiefly concerned with the degree to which a given increase in the extent of burn increases the fluid requirements In burns of more than 50 per cent of the body surface most observers believe that this linear relationship does not exist as it does in less severe burns (Fig. 10)

The type of fluid therapy given and the length of time between injury and initiation of therapy may well influence the volume of fluid required It is difficult to obtain reliable information in regard to this aspect of management It appears that fluid requirements are greater when therapy consists chiefly of electrolyte solutions and, conversely, they are less when most of the therapy is given in the form of colloid solutions Patients who show signs of circulatory collapse because of delay in fluid therapy may require larger volumes of fluids than patients with burns of comparable severity who are treated promptly

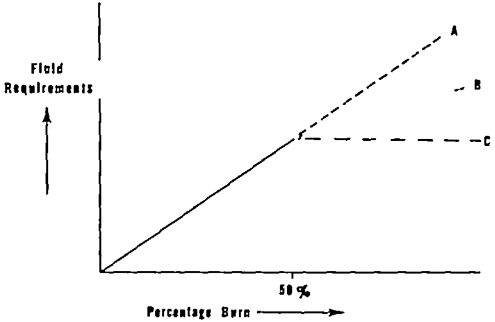

FIG. 10. In burns of less than 50 per cent, there appears to be a linear relationship between the extent of burn and fluid requirements. The nature of this relationship in burns greater than 50 per cent is not known. It is usually assumed to be like *C* but more likely approximates *B* and probably departs definitely from *A*

It has already been emphasized that the depth of burn is an important determinant of the fluid losses and consequently of treatment requirements Very extensive sunburn (first-degree burn) requires very little fluid therapy A patient with a 20 per cent deep burn however usually requires a considerable amount of replacement therapy

As to the rate of fluid loss Cope s exhaustive investigations furnish excellent information The losses are incurred most rapidly early after burning [4 5 6 19] The rate of edema formation then declines and fluid losses finally cease about 48 hours after burning, at which time edema is maximal (Fig. 11)

Resorption of Edema Fluid

Resorption of edema fluid seems to occur chiefly by way of lymphatic drainage In uncomplicated burns of minor extent the rate at which edema fluid is withdrawn from the wound approximates the rate of its accumulation (Fig. 11 curve A) In more extensive burns and particularly those complicated by infection the wound edema may persist for two or three weeks At times edema about the wound subsides but the load of fluids given as initial therapy is not excreted through the kidneys or the exudate Apparently the fluid leaves the wound and is translocated to other portions of the body

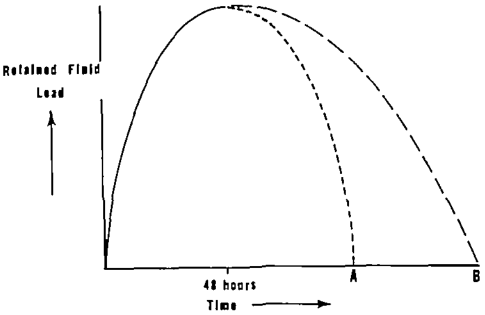

FIG 11 In small uncomplicated burns, the fluid given during early therapy is rapidly excreted in the manner indicated by parabola *A* In more extensive deep burns, visible edema may subside in five to seven days but excretion of the fluid load given as early therapy may be delayed for as long as three weeks (curve *B*) Translocation of fluids from the wound to other portions of the body is followed by gradual elimination via the kidneys and the exudate.

Of course this fluid is eventually excreted, but excretion may be delayed for days or weeks after all traces of visible edema have disappeared (Fig. 11 curve B) Delay in the excretion of the fluid load occurs characteristically in deep, extensive burns, and especially those complicated by invasive infection Fluid redistribution is a complex and unpredictable event.

Composition of Fluid Losses

This aspect of the fluid problem in burns is certainly the least understood Because of the controversy between investigators, several points of view are presented

PROTEIN Studies at the Massachusetts General Hospital have added much to the information concerning the protein content of fluid losses in burns [4 6] These data were derived from measurements of the composition of blister fluid and of lymph draining from burned areas. In both blister fluid and lymph the ratio of albumin to globulin is always higher than in the plasma This phenomenon is explained by the relative size of the protein molecules The larger globulin molecules appear to have greater difficulty in migrating across the injured capillary membrane

On the average human blister fluid contains 4 grams of protein

per 100 ml Unless infection supervenes blister fluid does not coagulate Regardless of the severity of the burn the plasma protein concentration of blister fluid is always less than that of the plasma It has been demonstrated that the increased protein content of lymph is a result of capillary damage and not merely a reflection of tissue lysis with the release of plasma proteins By injecting albumin tagged with certain dyes it has been shown that the increased lymph protein is undoubtedly derived from the plasma [6] The increased capillary permeability to proteins is limited to the burned areas and it does not occur at sites away from the wound

There is experimental evidence that one of the early changes after thermal injury is an increase in the protein concentration in the plasma [4] Although proteins are lost from the plasma into the burn wound water and electrolytes are lost more rapidly This increases the plasma protein concentration and tends to compensate for the oligemia resulting from fluid losses at the wound site by draining interstitial fluid from unburned tissues into the vascular system This occurrence probably represents one of the important mechanisms of compensation for the parasitic effects of the wound in untreated patients (Fig. 7) All investigators agree that the concept of plasma protein loss into the wound is a very important physiologic factor but there are differences of opinion as to the therapeutic implications of this concept Relatively large burns may be treated adequately by using only electrolyte solutions. The proponents of electrolyte therapy at the exclusion of other therapy as well as the proponents of whole blood and electrolyte therapy have maintained that there is little advantage in giving colloids if the colloids administered leak freely through the injured capillaries At present this disagreement has not been adequately resolved A further understanding of the various points of view can be gained from the publications cited at the end of this chapter [4, 5, 16]

Electrolytes Water and electrolytes freely permeate the normal capillary Burning affects water and electrolyte shifts directly through increased capillary hydrostatic pressure and indirectly through protein shifts Injury to tissue cells may be another important factor influencing the movement of water and electrolytes

In deep burns in mice Fox noted the loss of potassium from burned tissues and its apparent uptake in unburned tissues [10] This loss of potassium was accounted for quantitatively by an increase in sodium in the burned tissues this increase occurring over and above that expected on the basis of interstitial edema These data suggested that sodium is lost into burned tissues by the entrance of sodium into injured cells as well as by the accumulation of interstitial edema

Hypo-osmolarity of the extracellular fluid could be a consequence of the sodium shift into injured cells, and water would, therefore, shift into unburned tissues. Thus, a twofold fluid loss may occur—at the site of injury and in unburned tissue cells

This interpretation of the data would indicate that solutions hypertonic with respect to the sodium ion should prove more efficacious than isotonic solutions There is some evidence that this is true in the case of burned rats Whether it is also true in human beings is still to be proved It should be mentioned that Fox s data were derived from very deep burns that probably extended into muscle Tissue analyses in human burned skin are not conclusive as regards a significant uptake of sodium by injured cells

The bulk of evidence at present suggests that hypertonic sodium solutions should not be used in the treatment of burns If sodium solutions are given in hypertonic concentration, hypernatremia unquenchable thirst and intracellular dehydration occur

Regardless of the exact mechanisms involved the need for sodium therapy in burns is indisputable It must be remembered that citrated plasma contains approximately 160 mEq of sodium per liter and that dextran is marketed as a solution in physiologic saline Thus, the proponents of colloid therapy give large quantities of sodium, and some investigators believe that it may be the sodium and not the colloid that is chiefly beneficial However, the value of colloids is found ultimately at the bedside where it becomes obvious that electrolyte therapy alone is inadequate in a deep extensive burn Therefore, blood plasma expanders plasma or some combination of colloids must be given in order to treat these patients successfully

Experimental deep burns are characterized by a transient hyperkalemia This appears to result both from the release of potassium by burned tissue and from hemolysis of erythrocytes (225 cc of human erythrocytes contain approximately 23 mEq of potassium) Potassium changes during the first 24 hours are of little practical clinical significance Solutions containing potassium in more than minute quantities should certainly not be given during the first 48 hours

ERYTHROCYTES The amount of destruction of red blood cells (RBC) following thermal injury is highly variable In general, RBC destruction is a significant problem only in connection with deep burns It is minimal in second-degree burns, even those of large extent

The mechanisms of early RBC losses appear to be as follows

1 RBC's trapped in the burned area at the time of injury are hemolyzed These cells are hemolyzed at once and give rise to the hemoglobinemia and hemoglobinuria that is observed during the early period in extensive deep burns The finding of free circulating

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1 RBC's trapped in the burned area at the time of injury are hemolyzed These cells are hemolyzed at once and give rise to the hemoglobinemia and hemoglobinuria that is observed during the early period in extensive, deep burns The finding of free circulating

hemoglobin in the plasma of a recently burned patient indicates that the injury is severe A practical aspect of this condition is discussed under the topic Oliguria (p 37)

2 Delayed hemolysis is observed for 24 to 48 hours after burning It results from lysis of RBC that are partially damaged by heat. These RBC, which are eventually lysed, can be identified by their abnormal morphology [12]

3 Thombosis of blood occurs in the capillaries of burned tissues *and contributes to the RBC mass decrease*

4 The phenomenon of sludging is well demonstrated in burns [3] The magnitude of its contribution to the functional removal of RBC's is not known but it may be considerable

The clinical importance of RBC destruction was emphasized by Abbott[1] and Evans [8] Both investigators found that seriously burned patients frequently had severe anemia after the period of fluid re distribution They pointed out that once anemia is established, it is difficult to correct by blood transfusions, and that RBC replace ment should therefore be carried out during the early phase of treat ment Almost everyone now agrees that early blood transfusions are essential in the treatment of extensive deep burns The amount to be given should be determined by the amount of RBC destruction However, the amount of RBC destruction is difficult to measure ex perimentally and almost impossible to estimate clinically In a severe burn measurements of RBC destruction reported by different in vestigators have varied from 40 to 8 per cent of the RBC mass [18 21] Reported differences depend largely on various experimental methods This wide divergence of opinion may be reconciled by future research

From a clinical standpoint it is wise to assume that in a severe burn the RBC destruction is approximately 10 to 15 per cent of the RBC mass in the first 48 hours The best guide to therapy at present is that the deeper and more extensive the burn the greater the amount of transfusions required

TREATMENT DURING THE FIRST FORTY EIGHT HOURS

Burns differ from most conditions characterized by losses of water and electrolyte in that the rate volume and composition of fluid losses can be anticipated Clinical shock is a preventable syndrome providing adequate therapy can be instituted soon after injury How *successful a physician is in preventing shock depends on how soon* after injury he sees the patient and upon his ability to estimate losses before they occur In predicting losses some insight into pathologic physiology and proper estimation of the severity of injury are re quired

A patient s general condition may appear satisfactory in the first six hours following injury, although only little fluid therapy has been given Signs of circulatory decompensation often develop slowly once they occur treatment is often very difficult This insidiousness of the development of difficulty must be always kept in mind It must not be allowed to cause a delay in vigorous therapy

Clinical Signs and Symptoms of Fluid Deficiency

THIRST This is usually the first symptom Frequently it is intense and may not be completely relieved by therapy

The importance of thirst lies in the fact that a patient who is given access to unlimited amounts of water is in danger of developing water intoxication—a serious complication that Moyer has repeatedly emphasized.[16] The clinical syndrome of water intoxication may have been what was referred to as "early toxemia" in the literature on burns before 1940 Water intoxication is caused by intracellular edema resulting from dilution of the extracellular fluid In a normal subject osmotic pressure of the extracellular fluid is closely regulated and maintained within a remarkably narrow range by the osmoreceptors. Ingestion of water in the normal subject tends to dilute the extracellular fluid and to produce inhibition of antidiuretic hormone secretion by the posterior pituitary The result is a prompt renal excretion of water In a burned patient renal excretion is altered by the shifts of fluid into the wound and, possibly by an increased secretion of antidiuretic hormone With a decrease in osmolarity of the extracellular fluid because of ingestion of water that cannot be excreted the osmotic balance between the cells and the extracellular fluid is disturbed in such a way that water is shifted from the extracellular fluid into the cells Water intoxication is characterized clinically by headache tremor muscle twitching, blurring of vision vomiting, diarrhea disorientation, excessive salivation, and mania Generalized convulsions may occur in advanced cases

VOMITING This symptom may be a sign of circulatory collapse acute gastric dilatation paralytic ileus or a nonspecific effect of injury Vomiting occurs frequently in extensive burns and is a contraindication to the use of oral fluids soon after injury Vomiting is usually a sign of difficulty but it is of little help as a specific sign for fluid deficiency

CENTRAL NERVOUS SYSTEM Disturbances in the central nervous system are useful in following the progress of therapy Restlessness disorientation and maniacal behavior usually indicate that cerebral hypoxia exists and that fluid replacement should be intensified

Restlessness is commonly the first indication that therapy has

failed to keep pace with fluid losses It is a remarkably sensitive and useful sign Treatment consists of intensifying fluid therapy and administering oxygen Occasionally a prompt and beneficial effect is obtained by oxygen therapy alone Great caution must be exercised in the use of sedation in restless patients

Disorientation is more difficult to appraise In the first 24 hours after injury disorientation generally indicates a need for more intensive therapy After 48 hours disorientation is usually associated with emotional factors such as denial of illness or it may be a sign of invasive infection (see Chapter 7)

Mania is a complication indicating serious trouble It may be caused either by severe circulatory collapse by cerebral anoxia due to pulmonary damage or by water intoxication If it is caused by circulatory collapse vigorous fluid therapy, preferably via two or three veins simultaneously is indicated Therapy should also include administering 100 per cent oxygen by mask and withholding all types of sedation

PULSE RATE AND BLOOD PRESSURE *These signs are not as sensitive* indices of adequacy of therapy as they are in circulatory collapse due to hemorrhage A normal pulse rate and a normal blood pressure *do not indicate the absence of circulatory deficits,* for *serious fluid* deficits may be occurring while these signs are still normal It is not uncommon for example to see a burned patient who is restless and oliguric but who has a normal pulse rate and blood pressure Pulse and blood pressure should be taken and recorded every half hour during the early phase of burn therapy since serious difficulty is certain when the pulse rate suddenly increases or the blood pressure falls Usually a diminution in blood pressure is an indication for intensification of therapy with colloids

RATE OF URINARY OUTPUT This symptom is by far the best single index in determining adequacy of therapy

The urinary output must be measured at hourly intervals A urine flow of 30 to 50 cc per hour is adequate for an adult If this rate of flow is maintained serious trouble is rarely encountered and it may be expected that other signs of deficiency will not develop There are exceptions of course and a patient must be watched carefully for signs of fluid deficiency other than the rate of urine flow

What constitutes an ideal urinary volume is not known The range of adequate volume during the first 48 hours is probably wider than 30 to 50 cc per hour A urinary volume of 10 to 20 cc per hour for two or more hours is an indication for more energetic therapy A urinary volume of 100 cc per hour is a sign of over zealous therapy and indicates that the rate of fluid administration must be reduced Over

zealous therapy leads to overexpansion of extracellular fluid and to pulmonary edema

OLIGURIA A special problem is posed by the severely burned patient who is markedly oliguric or anuric shortly after injury Should the case be considered one of renal failure or should it be assumed that therapy has not been sufficiently intensive? This question is crucial, since the accepted method of treatment for acute renal failure (lower nephron nephrosis or hemoglobinuria nephrosis) is rigid fluid restriction Fluid restriction leads to almost certain disaster when applied to an inadequately treated patient

Before 1945 acute renal failure was reported to be a frequent complication of acute deep burns Since then, the incidence of this complication appears to have decreased Although the evidence is in conclusive experience has demonstrated that good fluid management serves as an excellent prophylaxis against acute renal failure in burns The value of prompt replacement of blood as prophylaxis against acute renal failure is generally accepted in cases of mechanical trauma When treatment has consisted exclusively of either blood or of elec trolyte solutions, severe oliguria or anuria may occur Under these conditions, the only possible course of action is intensive therapy with whatever fluid appears to have been deficient on the assumption that anuria is caused by inadequate therapy and that severe organic changes have not yet occurred in the renal tubules A water or plasma volume expander loading test may be given If the oliguria persists after 1 000 cc of a plasma volume expander and 1 000 cc of 5 per cent dextrose in water are given rapidly, renal failure due to organic changes is likely to be present Signs of fluid deficiency other than urine flow must then be used to gauge the adequacy of therapy If a patient becomes symptom-free but anuria persists it is justifiable to assume that acute renal failure is present and treatment should be continued with small amounts of fluid

The high frequency of oliguria and anuria due to insufficient therapy and the comparative rarity of acute renal failure accompanying thermal injury cannot be emphasized too strongly

Oliguria is often encountered in extensive second-degree burns while anuria is more commonly a complication of deep burns in which extensive intravascular hemolysis has occurred Renal tubular ne crosis has been observed at autopsy in some extensive burns but it has not been the primary cause of death In these instances of acute renal failure the burns were usually of such severity that ultimate survival would have been unlikely even in the absence of renal failure

PULMONARY EDEMA This condition may be caused by three

different factors (1) excessive fluid therapy (2) damage to the respiratory tract due to inhalation of noxious gases, and (3) invasive infection

Excessive therapy is becoming rare because of the improved fluid regimens that are being used Overloading the circulation can be prevented by maintaining the urine flow at the proper level By far the commonest cause of overtreatment is overestimation of the extent of burn with undue reliance on a fluid formula More conservative treatment is indicated in elderly patients who are likely to have some degree of cardiovascular renal disease Overtreatment is not an uncommon complication of treatment in infants [14] In general the danger of undertreatment is greater in the young adult and the danger of overtreatment greater in the older patient and in infants

A history of inhalation of fumes serves as a warning that tracheobronchial damage may exist, therefore conservative fluid therapy is indicated (see Chapter 6)

The importance of invasive infection as a cause of pulmonary edema has not been widely recognized Acute left ventricular failure is a common immediate cause of death in patients who have septicemia, with or without burns and with or without parenteral fluid therapy Septicemia in severe burns often becomes evident three to five days after injury (see Chapter 7) This is also the time when visible edema subsides and fluids are being redistributed When death in pulmonary edema occurs at this time it has been customary to ascribe it to excessive fluid therapy This may be a serious error of judgment. It is believed that the association of pulmonary edema and septicemia will become more evident when the frequency of septicemia as a common complication in severe burns becomes more widely recognized.

Treatment of Minor Burns

In general intensive intravenous therapy is required only in burns of more than 20 per cent of the body surface Some rather extensively burned patients (30–35 per cent) do remarkably well with only minimal supportive therapy but these are very exceptional cases In second-degree burns up to 20 per cent, oral Haldane s solution is usually adequate. This solution is prepared by dissolving 3 to 4 grams of salt (½ teaspoonful) and 1 5 to 2 grams of bicarbonate of soda (½ teaspoonful) in a quart of water (Fig. 12) The solution should be thoroughly chilled for optimal patient tolerance If vomiting occurs lactated Ringer s solution can be given intravenously in amounts of about 2 cc. per kilogram for each per cent of burn

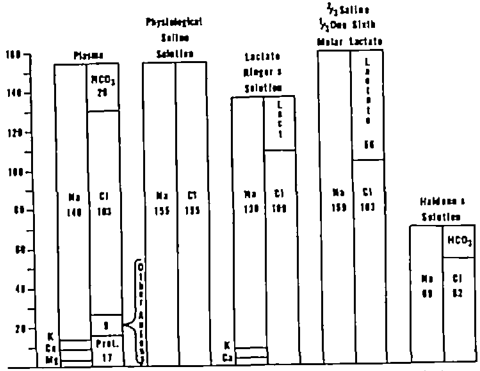

FIG 12. Comparison between the composition of various electrolyte solutions used in the treatment of burns with the composition of normal plasma.

In connection with oral fluid therapy, several points require emphasis

1 Water not containing electrolytes must be avoided because of the danger of water intoxication

2 Isotonic electrolyte solutions are poorly tolerated and usually induce nausea and vomiting.

3 If vomiting occurs, oral therapy must be discontinued since the loss of gastric juices may cause additional electrolyte deficits

Treatment in more severely burned patients involves painstaking elaborate and time-consuming measures In the case of disaster oral electrolytes would probably be the only form of therapy available for the great majority of patients The recommendation limiting the use of oral electrolytes to small burns is an expression of conservativism There are good reasons for believing that oral electrolytes are also useful in more extensive burns and that they can be life saving pending the availability of whole blood and other intravenously administered colloids (see Chapter 12)

The First 24-Hour Period

FLUID FORMULÆ The use of a burn formula is recommended for estimating the fluid requirements during the first 48 hours if a few precautions are observed It is clear from the discussion of pathologic physiology that fluid requirements are governed by many complex and

imperfectly understood variables and that it is impossible to express the intricate physiologic phenomenon of fluid shifts in burns in simple arithmetic terms. A burn formula expresses the fluid needs of a patient about as well as the average digitalizing dose expresses digitalis requirements Just as the internist is guided in the administration of digitalis by certain signs and symptoms the surgeon treating burns varies the fluid requirements predicted by the formula in accordance with the clinical response of the patient

The welfare of a burned patient is best served by scrupulous attention to all clinical details There is no substitute for this Formulae are surely not designed to take the place of careful frequent clinical appraisal and adjustment of the treatment regimen However they are invaluable and practical as an initial rough estimate of fluid therapy

The first formula based on surface area was proposed by Cope and Moore in 1947 This technique represented a substantial improvement over reliance on the hematocrit as a guide to therapy As its proponents recognized this formula prescribed excessive amounts of fluid for some patients.

The Evans Formula This formula was introduced in 1952 It made an allowance for the weight of the patient as well as the extent of the burn [9] Inclusion of the weight parameter was an important step in the right direction The formula is deficient in that it does not make any allowance for the depth of burn, a shortcoming that all formulae proposed to date have in common

Evans based his formula on the finding that, six hours after a dog receives a standard 20 per cent burn, there occurs a decrease in plasma volume of approximately 1 cc for each per cent of body surface burned per kilogram of weight He observed comparable changes in plasma volume in patients who had 20 per cent body burns that presumably had not been treated. By assuming that the plasma losses are proportional both to body weight and extent of burn Evans concluded that the plasma requirements were equal to 1 cc per kilogram for each per cent of burn. He arbitrarily considered the electrolyte requirement equal to the plasma requirement. In addition he added 2,000 cc of nonelectrolyte fluids to the regimen to cover insensible fluid loss and to insure an adequate output of urine

The Evans regimen consists of the following solutions for the first 24-hour period (1) colloids 1 cc per kilogram of body weight for each per cent of body surface burned (2) electrolytes (physiologic saline solution) 1 cc per kilogram of body weight for each per cent of body surface burned and (3) nonelectrolytes, 2 000 cc. of 5 per cent glucose in water administered intravenously or water adminis

tered orally Evans recommended one half these amounts of colloids and electrolytes during the second 24-hour period

In view of the many assumptions and approximations on which the Evans formula is based, it is surprising to find that the formula is a remarkably useful guide to therapy Despite theoretical objections surgeons in many centers attest to its excellence on the basis of abundant clinical experience. Many patients do well without any deviation from the formula

Some precautions are pertinent The first precaution applies to all formulae, as stated previously a formula is only a rough guide, and adjustments in individual patients are often required The second precaution limits the applicability of the formula to burns of 50 per cent or less. In more extensive burns fluid requirements are estimated as though only 50 per cent of the body surface had been burned Thus for the first 24-hour period estimates of fluid requirements for an adult weighing 80 kilograms and having a 70 per cent burn are 4 000 cc (80 x 50) of colloid 4 000 cc of electrolyte solution, and 2 000 cc of nonelectrolyte solution The reason for introducing this limiting factor is that the extent of burn fluid requirement relationship is not known in burns exceeding 50 per cent of the body surface This relationship is probably linear up to 50 per cent In Figure 10, therapy based on line A is usually excessive Evans assumed a relationship of the type shown in line C

The Brooke Formula This formula is a slight modification of the Evans formula [20] Whether it is an improvement over the Evans formula might be debatable The Brooke formula differs from the Evans formula in that an electrolyte colloid ratio of 3 1 is proposed in contrast to Evans s 1 1 ratio The formulae are identical as regards recommendation of total fluid volume

Some explanation of the suggested alterations to Evans s excellent regimen is pertinent. After acquiring experience with the Evans formula physicians at the Brooke Army Hospital, Brooke Army Medical Center were interested in learning whether the colloid requirements could be decreased with a corresponding increase in the electrolyte requirements This interest was stimulated partly by data indicating the importance of sodium salts in the treatment of shock in animals and partly by the fact that electrolyte solutions are much cheaper and might be secured in larger quantities in case of disaster It appeared that increasing the ratio of electrolyte to colloid was beneficial Patients so treated had remarkably smooth clinical courses

According to the Brooke formula the electrolyte requirements during the first 24-hour period are (1) colloids, 0 5 cc per kilogram of body weight for each per cent of body surface burned, (2) electro-

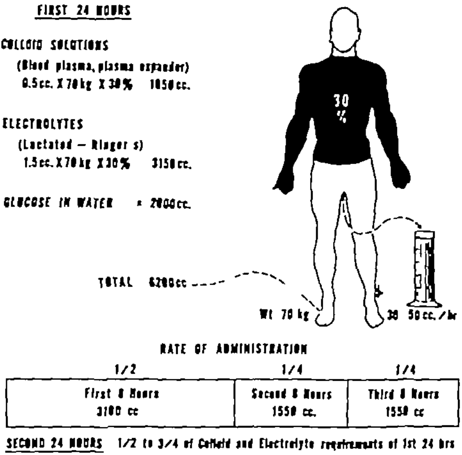

FIG 13 Application of the Brooke Formula in the estimation of fluid requirements in a patient weighing 70 kilograms with a 30 per cent burn.

lytes, 1 5 cc per kilogram for each per cent of body surface burned and (3) 2,000 cc of glucose in water The second 24-hour period requirements for colloids and electrolytes are about one half those for the first 24 hours (Fig 13)

In applying this formula to burns larger than 50 per cent, the same precaution is to be taken as in the Evans formula requirements must be calculated as though only 50 per cent had been burned Usually it is not necessary to give more than 10 liters of fluid to any patient *regardless of the extent of burn and weight of patient in the first 24* hours If in a burn of more than 50 per cent fluid therapy based on the 50 per cent restriction fails to prevent signs and symptoms of circulatory failure therapy may be cautiously increased In such cases relationship (B) Figure 10 obtains and intensification of therapy may be lifesaving

CHOICE OF ELECTROLYTE SOLUTION Sodium chloride in 0 9 per cent solution—physiologic or normal saline—is used extensively, This *solution was recommended by Evans It is inexpensive and available* in any hospital However it is far from ideal as an electrolyte re

placement solution Its chief drawback is the excessively high concentration of chloride The normal concentrations of plasma sodium and chloride are approximately 140 and 103 mEq per liter respectively (Fig. 12) In a 0 9 per cent saline solution, the concentration of both sodium and chloride is 155 mEq per liter and consequently such a solution is markedly hypertonic to plasma as regards chloride Massive infusions of a 0.9 per cent saline solution in burned patients is usually associated with hyperchloremia, the plasma chloride concentration may increase to a range of 110 to 120 mEq per liter Hyperchloremia is an undesirable and unnecessary complication that is readily prevented by giving a balanced electrolyte solution in place of physiologic saline solution One of the undesirable effects of hyperchloremia is that it tends to produce acidosis.

A balanced electrolyte solution is preferable.[11] Many such solutions are commercially available none being more beneficial than the others A standard, acceptable balanced solution is lactated Ringer s (Hartmann s) solution This is not to be confused with plain Ringer s solution which like saline, contains an excessive concentration of chloride. If a balanced electrolyte solution is not available, a solution containing 159 mEq of sodium and 103 mEq of chloride per liter can be prepared by mixing 0 9 per cent saline solution and ⅙ molar lactate solution in proportions of 2 volumes of saline to 1 volume of ⅙ molar lactate

The composition of various electrolyte replacement solutions is shown in Figure 12. The 0.9 per cent saline and the saline lactate mixture are slightly hypertonic to normal plasma as regards sodium Lactated Ringer s solution is slightly hypotonic with respect to sodium and slightly hypertonic with respect to chloride

CHOICE OF COLLOID Plasma has been used most widely and its value has been proved in the treatment of burns Its chief drawback is the danger of transmitting the virus of homologous serum hepatitis Dextran in saline, a plasma volume expander, has been of definite clinical value Dextran, as it is now prepared and marketed is a safe solution having colloid osmotic effects equivalent or possibly superior to those of plasma. For burns that are predominantly second degree, most of the colloid requirements can be met by either plasma or dextran.

How much blood should be used is debatable Evans,[8] Abbott,[1] and Moyer[16] have enthusiastically advocated the use of blood Quinby and Cope on the other hand, believe that the present-day tendency may be to give too much blood [17] For burns of 35 per cent or more Evans recommended a blood plasma ratio of 2 1 or administration of all the colloid as blood Moyer believes that no colloid

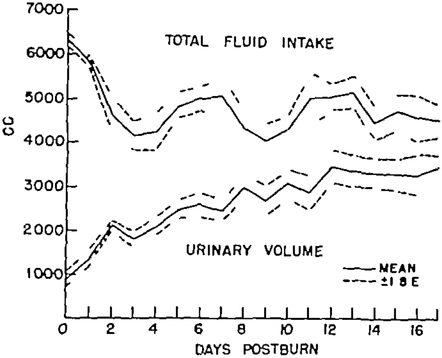

FIG. 14 The urine volume characteristically increases gradually but steadily after 48 hours. The data shown in this figure were obtained in 24 severely burned patients.

These include collapsed veins poor tissue turgor a small tongue volume oliguria and hypotension It is strange that symptomatic salt depletion occurs *in the presence of an increased total body sodium*. A similar distributional paradox occurs in some cases of congestive heart failure Under these circumstances, there is no choice but to give fluids containing sodium The amount to be given depends *upon the individual case The aim of therapy should be to give a min imal* sodium load that abolishes the signs and symptoms The plasma sodium concentration is of greater value in regulating the water needs than in regulating the sodium needs

Potassium

The rule that potassium should not be given in the presence of oliguria is applicable to burns Potassium administration must be *avoided during the first 48 hours following injury* The potassium con tent of lactated Ringer s solution is very small (4 mEq per liter) and these small amounts are probably not harmful

After 48 hours, the urine volume generally increases gradually (Fig. 14) *Potassium therapy at this point is not only safe but definitely indicated* A shift of potassium from the extracellular to the intra cellular fluid compartment can be demonstrated within a few days after thermal injury Hypokalemia has been observed in patients

who have not received potassium, and this may or may not be associated with untoward symptoms It appears wise to allow a patient access to potassium and to administer routinely 80 to 100 mEq daily by mouth or by vein on about the third postburn day The dangers of excessive administration are very small since most patients have no difficulty in excreting potassium by way of the kidneys Whether potassium should be given as a chloride or phosphate is not of critical importance Potassium chloride is adequate and may be used unless there is hyperchloremia Three grams of potassium chloride may be given orally two or three times a day Mixtures of alkaline potassium salts are available commercially and are generally preferable to the chloride salt[1] If the patient can tolerate a normal diet, he probably does not require a potassium supplement

Blood

Transfusion requirements are discussed in Chapters 7 and 8 They may be very large and of critical importance

LABORATORY CONTROL

It is clear that clinical guides are of greatest usefulness in the treatment of an acute burn While extensive laboratory studies have been of immense help in research, only a limited number of laboratory determinations are necessary as guides to therapy

In moderate burns the hematocrit and concentration of plasma sodium are the only necessary measurements In extensively burned patients a battery of serum and urine electrolyte determinations may be required The serum protein concentration is altered more or less predictably and need not be measured routinely (see Chapter 8)

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CHAPTER 4

Initial Local Care

THE STIMULUS that provokes the physiologic derangements is the burn wound The effect of the wound is directly related to the amount of tissue destroyed Therefore, depth of injury as well as extent of body surface burned is important in assessing the magnitude of trauma

DEPTH OF THE BURN

Although different classifications have been used to differentiate various depths of burns in recent years, it has been common practice to divide burns into three categories first degree second degree, and third degree First-degree and second-degree burns are known collectively as partial thickness burns and third-degree burns as full thickness burns Since the systemic and local changes are directly related to the amount of tissue destroyed this classification is probably an oversimplification Greater clarity might result if second degree burns were further divided into superficial second-degree and deep dermal burns Third-degree burns should be classified as full-thickness skin loss and as deep third-degree burns in which the injury involves the underlying subcutaneous tissue muscle or bone

First Degree Burns

A first-degree burn involves only the outer layer of the epidermis the stratum corneum (Fig 15) It is characterized by erythema that appears after a variable latent period A first-degree burn may follow prolonged exposure to bright sunlight or instantaneous exposure to more intense heat Since tissue destruction is so superficial minimal systemic derangements occur Pain and a slight amount of edema are the chief problems The uncomfortable burning sensation and pain usually subside after 24 hours unless the first-degree burn is quite extensive such as that seen in severe sunburn Since this is only a

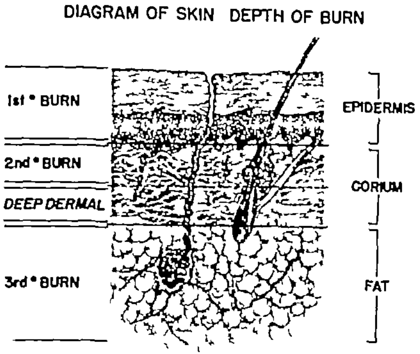

FIG 15 Schematic outline of cross section of skin. First-degree burns involve only a portion of the epidermis and heal rapidly because the deeper layers of the epidermis are not involved. Second-degree burns involve the upper portion of the corium and many islets remain which proliferate to cover the area in about 14 days. Deep dermal burns extend into the corium and the only epithelium remaining is the lining of the sweat glands and hair follicles. Third-degree burns involve the full-thickness of skin and extend down to subcutaneous fat.

superficial injury the capacity of the epidermis to prevent infection is retained Healing usually takes place uneventfully Within three to six days the epidermis peels off in small scales There may be residual redness for a few days, but no scarring results

Second Degree Burns

A second-degree burn is a slightly deeper injury than a first-degree burn It involves all the epidermis except the deeper portion of the stratum germinativum (Fig 15) Second-degree burns are characterized by blisters whose fluid has a chemical composition similar to that of plasma (see Chapter 3) A second-degree burn is usually accompanied by considerable subcutaneous edema

The base of the blisters shows varying degrees of redness according to the depth of the burn The rate of healing is dependent on the depth of skin destruction and on whether or not infection occurs In *superficial partial thickness burns* parts of the stratum germinativum are intact and the burned surface retains its epithelial regenerating capacity Healing occurs uneventfully in a period of 10 to 14 days unless infection supervenes

Deep dermal burns are injuries that extend down through the stratum germinativum and, in some areas, into the superficial portion of the corium (Fig. 15) Epithelial regeneration takes place principally from the epithelial lining of sweat glands and hair follicles

In the event of infection, deep dermal burns are readily converted to full thickness injury However, if the wound is properly protected it will be covered with a thin layer of epithelium in 25 to 35 days There may be slight scarring. Not infrequently this thin epithelium is injured, giving rise to denuded areas and further scar formation When the thin epithelial covering of a deep dermal burn is stretched by motion, blister formation may occur Small watery blisters that form may rupture and become infected unless they are protected

The deep dermal burn is of significant clinical importance It is difficult to diagnose It causes physiologic derangements that are more severe than those following superficial second-degree injury It heals spontaneously if kept free from mechanical and bacterial trauma If infection supervenes it becomes converted into full thickness injury and grafting is necessary

Third-Degree Burns

Third-degree burns are very severe forms of injury The entire dermis and corium down to the subcutaneous fat are destroyed by coagulation necrosis (Fig. 15) Thrombosis occurs in the small vessels of the underlying tissues Increased capillary permeability and edema are greater than in a second-degree burn In two or three weeks, the full thickness dead skin liquefies, partially by autolysis and partially by leukocytic digestion This process is usually accompanied by suppuration Capillary tufts and fibroblasts organized into granulating tissue are found beneath the eschar

Deep third-degree burns are considerably different from the third-degree burns that involve only full thickness skin loss If the burns extend into the subcutaneous fat, liquefaction occurs in that area Burns that extend into the muscle cause increased destruction of red blood cells and they may cause serious infections The physiologic derangements that occur in deep third-degree burns may be severe, even when they are of limited extent

The management of full thickness burns consists in the removal of the eschar and application of skin grafts to cover the wound If grafting is not carried out, a thick layer of granulating tissue will form, followed by contracture of the area The only method of epithelization in this type of burn is slow proliferation from the wound edges that usually occurs at the rate of about one-eighth of an inch per week The granulations become soft, overabundant and infected, thus hindering

epithelization After months or even years the wound might heal but not without considerable scarring and disfigurement.

CLINICAL DIAGNOSIS OF DEPTH OF BURN

Even in the most experienced hands the diagnosis of the depth of burn is most difficult because there are no definite clinical criteria for the degree of burn This difficulty might be expected because there are various gradations of injury in the extensive burn The central area of the burned surface may be full thickness with a surrounding zone of deep dermal and superficial second-degree burn and first degree burn at the periphery One depth of injury seems to fade into the other in such a way that definite demarcation and gradation is almost impossible

However there are certain reasonably reliable guides for estimating the depth of the injury (Table 3)

Table 3. Characteristics of Various Depths of Burns

DEPTH OF BURN	CAUSE	SURFACE	COLOR	PAIN SENSATION
First degree	sun or minor flash	dry no blisters	erythematous	painful, hyperesthetic
Second degree	flash, hot liquids	blisters, moist	mottled red	painful hypesthetic
Third degree	flame	dry	pearly-white or charred	little pain, anesthetic

First-degree burns usually occur after gas explosions brief contact with hot liquids or prolonged exposure to sunlight. They appear as a simple erythematous flush First-degree burns are dry and quite painful blistering seldom occurs

Second degree burns are caused by short periods of exposure to intense flash heat or contact with hot liquids or they may form the peripheral zone of a deeper flame burn They are frequently characterized by the formation of blisters The surface is mottled red or pink in appearance and it is usually moist, because a plasma like fluid exudes from the injured area A second-degree burn is quite painful and sensitive to the air *It is almost impossible to make an early diagnosis of a deep dermal burn* The surface may be moist but the exudate that forms is not as profuse as in the superficial second-degree burn The surface has a mottled appearance with a predominance of white rather than pink or red areas.

Third-degree burns are generally caused by flames or contact with hot objects Electrical burns are almost invariably third-degree Since

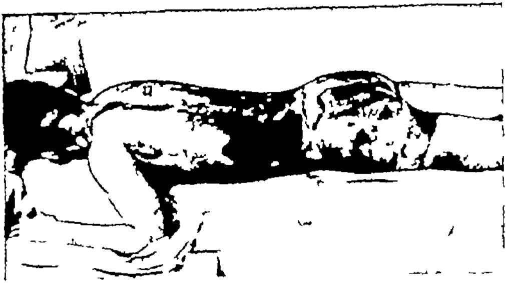

FIG 16. This 26-year-old male sustained third-degree flame burns on his back. The dark area in the center of the back shows typical charred full-thickness skin loss. The area was dry and insensitive to pain. Other less deep third-degree burns have a pearly white, dry appearance.

the entire layer of the skin is involved in a coagulation necrosis, the third-degree burn is usually dry and pearly-white or charred in appearance (Fig. 16) The skin feels leathery, in contrast to the moist soft surface of a partial thickness burn Third-degree burns are not very painful In fact, the area is almost insensible because the terminal nerve endings are inactivated by the deep injury The impairment in sensation has been used clinically as a test for depth of skin loss.[9] A hypodermic needle may be used to test pain sensation in the injured area This so-called "pin prick test" may show greatly reduced pain sensibility which is indicative of full-thickness injury If there is increased sensitivity to pain or only slightly diminished pain sensibility most likely the burn is partial thickness (Fig. 17) *Deep third-degree burns* that extend into the other layers beneath the skin are characterized by a charred appearance that is initially sunken and hard

AIMS OF LOCAL CARE

The primary aims of local care are the prevention and control of infection and the closure of the contaminated wound as soon as possible Systemic supportive therapy in fluid and electrolyte replacement should be instituted before any attempt is made to care for the burn wound

There are several principles of local care

1 Clean the burn wound and remove all pieces of detached

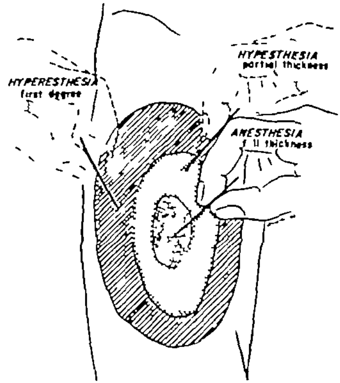

FIG 17 Pain sensitivity test for depth of burn. The testing of the burned area for pain sensitivity with a sterile needle aids in determination of depth of burn. A first degree burn shows hyperesthesia. A second-degree burn may show some decreased pain sensibility (hypesthesia), but a third-degree burn has the nerve endings inactivated and is anesthetic. In a cooperative patient, this is a very useful test for depth of injury

epithelium Dirt and dead tissue remaining on the wound provide an excellent culture medium for bacterial proliferation

2. *Prevent further destruction of the remaining viable epithelium* Mechanical cleansing should be gentle and irritating local applications must be avoided

3 *Produce an environment on the burned surface that is unfavorable to the growth and multiplication of bacteria* The surface of a burn should be kept as dry as possible by providing good drainage for the serum that exudes.

4 *Rest the injured part by immobilization*

5 *Aid the rapid separation of burn slough and at the same time prevent invasive infection and provide a suitable surface for grafting.*

6 *Apply skin coverage as soon as possible*

7 *Secure healing in a minimum period and thereby permit early motion and minimal loss of function*

8 *Cause as little pain as possible*

9 *Carry out these objectives without overcommitting the already decreased body reserves.* Frequent anesthetics may prevent an optimal systemic response to the effects of the extensive burn wound

IMMEDIATE CLEANSING OF THE BURN WOUND

After fluid therapy has been instituted, attention may be directed to the definitive care of the wound If the patient is admitted in poor condition local therapy must be postponed until adequate resuscitation has been achieved by vigorous fluid therapy (see Chapter 3)

Every effort should be aimed at minimizing further contamination and achieving a surgically clean wound. If some burned clothing adheres to the injured surface it must be soaked off All personnel who come in contact with the patient must be masked The patient is taken to a clean dressing room or operating room where a strictly aseptic technique can be carried out with attendants in sterile gowns and gloves The temperature of the room should be about 80° F and currents of air should be avoided because they cause increased discomfort. Anesthesia must be avoided The cleansing technique produces considerable discomfort but no unusual pain. Intravenous morphine analgesia is usually sufficient.

The burned areas are cleansed thoroughly All debris and detached epidermis must be removed (Fig. 18) Greases or ointments that have been applied may be removed with soap Tars and other oily preparations may be dissolved with benzene Alcoholic soaps and scrubbing brushes must never be used because they cause unnecessary trauma to the remaining viable epithelium The areas are cleansed with bland white soap and water at a temperature of 100° F This soap may be applied with soft, moist gauze pads and removed by irrigation with sterile water The surrounding normal skin is shaved

All blisters are broken and the devitalized epithelium is cut away with sterile scissors. Some surgeons favor leaving unruptured blisters and blebs because they feel that the epidermal covering provides a good dressing.[11] However most blisters break before complete healing occurs leaving devitalized tissue on the wound surface where bacteria will proliferate rapidly Firm thick blisters that occur on the palms of the hands may be left unruptured occasionally because they have a tough covering and are not likely to be broken before epithelization occurs

After all detached epidermis has been removed, the burn wound is again washed gently with soap and irrigated with copious amounts of sterile warm water The entire procedure should be carried out with the same careful surgical technique that is observed in performing an abdominal operation Several changes of sterile towels and sheets may be necessary during the cleansing procedure After the burn wound has been rendered as clean as possible, a decision must be made as to the type of further local care The aims of local care can be achieved

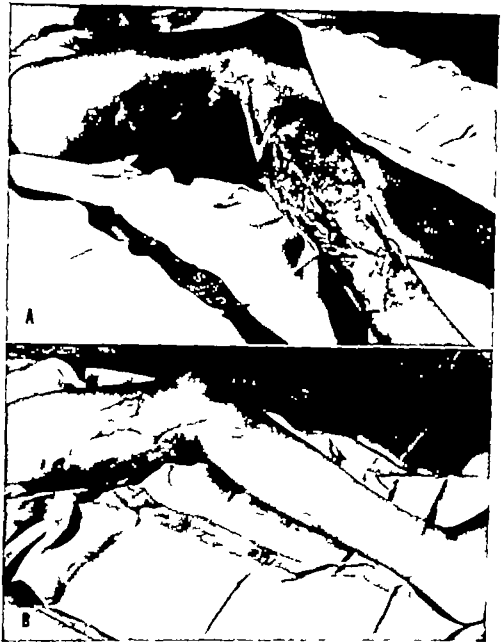

FIG. 18 *A* A partial-thickness burn of the right lower leg sustained by a 9-year-old boy when he was accidentally scalded by hot water The thin blisters are typical of second-degree burn.

B The blisters have been broken and all detached epithelium has been cut away The area has been cleansed gently with soap and water and care has been taken not to injure remaining viable epithelium. The wound healed uneventfully in 16 days under an occlusive dressing

by occlusive dressings or by exposure These two methods do not constitute two distinct schools of thought but they are techniques that may be used to complement each other

THE OCCLUSIVE DRESSING METHOD

Occ usive pressure dressings for the treatment of the burn wound were first introduced in 1942 by Allen and Koch [2] The observations of Cope in the Cocoanut Grove fire,[11] of Evans,[14] and of many others[1] have attested to the value of this method of treatment.

The aims of a good dressing, as pointed out by Allen and Koch, are to cover the open wound by the best available means in order to protect it from the constant danger of re infection A good dressing, how ever, does not fix or destroy any part of the skin which remains viable It provides for the drainage of the serum It exerts a uniform, moderate pressure, and it can be removed easily The dressings should be applied in such a way that the injured part is kept at rest.

Initially it was believed that firm mechanical pressure would inhibit the amount of exudate that flowed from the wound thereby de creasing the fluid loss In the past several years there has been evidence that such pressure does not decrease fluid loss appreciably, it only shifts the collection of fluid to the interstitial spaces proximal to the wound.[18] Since protection of the wound rather than its compression is the most important feature of dressings the term pressure dressing' is gradually being abandoned in favor of occlusive or absorptive dressing.' Dressings are applied with even resilient com pression in such a way that they eliminate dead spaces, they also limit venous and lymph stasis and produce a splinting effect

The original dressing technique entailed applying a few layers of fine mesh gauze impregnated with petrolatum directly on the wound Several flat, dry sterile gauze pads and abundant gauze fluffs mechanic s waste or sea sponges were wrapped over this first layer The dressing was held in place by an elastic bandage or stockinette applied in such a way that an even pressure was achieved over the entire burned surface

Experience has shown that, in most instances, the initial layer was too heavily impregnated with petrolatum This caused maceration of the wound edges In recent years a single layer of lightly impregnated petrolatum gauze or of dry fine mesh gauze has been utilized Lightly impregnated petrolatum gauze can be made easily by placing a roller gauze bandage in a jar then filling the jar with pe rolatum and autoclaving The tightly wound roller bandage is removed and the excess petrolatum is scraped away from the outer layers leaving a roll of lightly impregnated petrolatum gauze (see Fig 47 p 109)

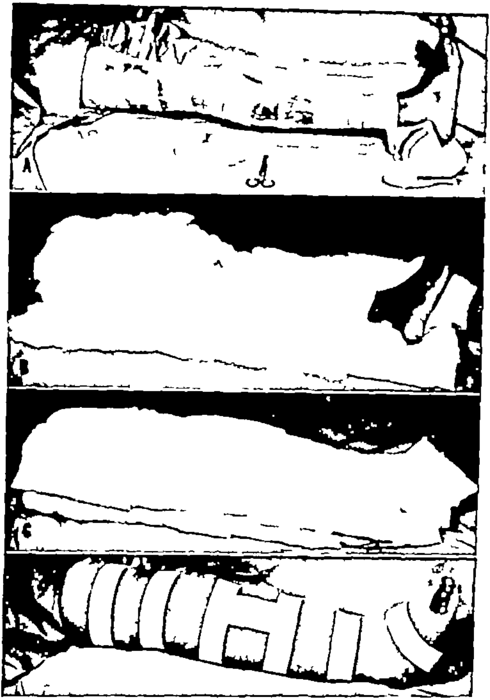

FIG 19 *A* Technique of application of an occlusive dressing After initial cleansing and removal of all debris and detached epithelium, the surface should be covered with fine-mesh gauze. In this instance lightly impregnated petrolatum roller gauze was used. Individual strips were applied in a circular fashion. When a continuous circular bandage is used, it does not conform evenly to the part and may become constrictive if excessive edema occurs. It is important that this first layer be applied smoothly and without wrinkles.

B Large abdominal pads have been placed beneath the leg. The petrolatum-impregnated gauze has been fixed in place with a single layer of dry 4 x 8 inch gauze pads, and a large layer of fluffed gauze is being placed over the extremity

C A final layer of large abdominal pads is placed over the bulky layer of fluffed

A common misconception is that petrolatum impregnated gauze should be used because it does not stick to the wound surface, therefore it causes less pain when a dressing is removed. This is rarely true, unless macerating amounts of petrolatum are used. The aim of a good dressing is to provide absorption in order that the wound surface may be kept as dry as possible, thereby producing an environment that is not conducive to bacterial proliferation. Almost any material that is placed on a wound will adhere to the area if a dry surface can be maintained.

Nylon and other finely woven materials have been used as an initial layer in the hope that they would not stick to the injured surface. The disadvantage of these finely woven materials is that the minute interstices become filled with dried exudate and prevent the absorption of fluid from the wound surface into the bulky part of the dressing. Thus, a moist surface is obtained and bacteria can multiply rapidly forming abundant purulent exudate that is held on the wound.

Lightly impregnated petrolatum gauze and dry, fine mesh gauze are the most satisfactory materials for direct application to a burned surface. Lightly impregnated petrolatum gauze is advantageous because it can be applied easily and smoothly without wrinkling and without the formation of dead spaces. A very absorptive, bulky layer of fluffed gauze or washed gauze may be placed next to the initial layer. The outer portion of the dressing may be formed by using several large, absorptive abdominal pads. A considerable bulk provides maximum absorption and permits the application of an even, resilient compression. A dressing must be fixed in place with a cotton elastic bandage, stockinette, or preferably a conforming bandage (Fig. 19).

A conforming bandage has recently become available. It is a semi-elastic, cotton gauze bandage that is made by treating roller gauze bandage with concentrated sodium hydroxide. The sodium hydroxide solution causes the cotton fibers to swell and to expand within the spiral structure of the yarn. As a result, the cloth shrinks and becomes semi-elastic. The surface irregularities, which result from the kinking, intermesh as each layer of bandage is added. The individual layers

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gauze. Although the foot was not involved, the dressing extends down over the foot. When the terminal portion of the extremity is not incorporated in the bandage there is a tendency for excessive edema formation.

D The occlusive dressing has been completed by an outer layer of conforming bandage. This bandage has been applied in such a way that there is even resilient compression over all areas. A bulky dressing of this type immobilizes the extremity and a splint is unnecessary. Adhesive tape has been used to anchor the dressing in place. By labeling the dressing, information is always readily available as to the time of burn, time of application of the dressing, and the type of immediate covering of the wound.

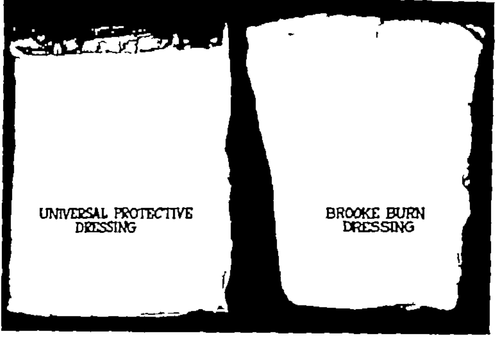

FIG 20 Two types of one-piece burn dressing *The Universal Protective Dressing* is a commercially available burn pad that serves as an excellent initial dressing for the burn wound. It is lined with fine-mesh gauze and can be applied directly to the injured area. The Brooke Burn Dressing is made from standard absorbent cotton and bolt gauze. It is thicker and more pliable than the Universal Protective Dressing.

interlock and the bandage conforms to the anatomic part The fabric is composed of 100 per cent cotton and is extremely light in weight It is cool and it permits the application of an even compression without constriction An appreciable saving results from its use because it is much less expensive than cotton elastic or crepe bandages

Great care must be taken in applying a dressing in order to produce even *resilient compression without constriction Thin dressings with* restrictive elastic bandages may give a tourniquet effect Local pressures of remarkably low amounts may impair the circulation In a study by Halpern and co-workers skin temperature measurements showed a definite effect with pressures as low as 20 mm of mercury [15] If it appears that the dressing does not immobilize the area adequately a wooden or plaster splint may be applied outside the dressing. Final bandages must be secured in place with an adequate amount of adhesive tape to keep them well anchored If any portion of an extremity is injured the entire extremity must be incorporated in the dressing to prevent edema of the terminal portion

Universal Protective Dressing

In an attempt to simplify the application of an adequate dressing, particularly in times of disaster, an excellent one piece burn pad

known as the Universal Protective Dressing (Fig 20) has been developed under the auspices of the Subcommittee on Burns of the National Research Council [4], [14] This dressing is composed of an inner surface of dry, fine mesh gauze The intermediate layer is composed of a one-inch layer of absorbent cotton and many layers of absorbent cellulose A simple, water repellent cotton fabric serves as an outer layer The dressing has an excellent absorptive capacity and can be applied quickly and effectively It is made in two sizes 22 x 36 inches to use on a leg, and 22 x 18 inches to cover an arm. It is packed with two rolls of conforming cotton bandages in a brown paper covering. It has been standardized as a field gauze compress for use in the Armed Forces.[4]

Brooke Burn Dressing

Another one piece dressing has been designed at Brooke Army Hospital Brooke Army Medical Center It is made from easily procured, standard items—absorbent cotton and 36-inch bolt gauze [13] A one-half inch layer of absorbent cotton, a section of soft, fluffed gauze made by folding over several layers from the bolt, and an additional one-half inch pad of cotton are encased in a large, single layer of gauze (Fig. 21) This dressing is thick, absorptive and very pliable. A layer of fine-mesh gauze either dry or lightly impregnated with petrolatum, should be placed over the wound before the dressing is applied It has been found advantageous to prepare several sizes of dressings to fit various parts of the body, i e whole leg, whole arm thigh lower leg, upper and lower arm The sections for the thigh and whole leg can be used on the trunk The dressings are made wider at the top than at the bottom in order to conform more accurately to the shape of an extremity This dressing can be made in any hospital by unskilled attendants or by volunteer workers It is more suitable for application after grafting than the Universal Protective Dressing because it is more pliable and it can exert a more evenly distributed pressure over the grafts.

Subsequent Dressing Changes

The time for subsequent dressing changes is regulated by the necessity for keeping the wound as clean as possible In some partial-thickness burns an adequate dressing may be left in place for 10 days or even longer while in other burns the dressings must be changed as frequently as every other day The dressings must be changed when it is believed that the burned surface has become unduly moist and may allow bacterial proliferation They should be changed whenever the bandage is stained because a soaked bandage

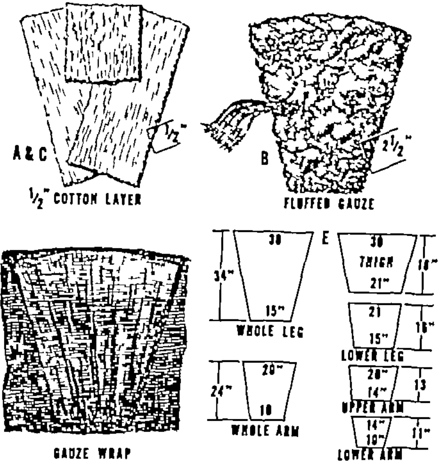

FIG 21 Construction of Brooke Burn Dressing An initial layer of absorbent cotton *A* is covered with a thick layer of fluffed gauze *B* made by folding over several layers from the bolt. A second layer of cotton *C* is added and the entire dressing is wrapped with a single layer of gauze as in *D* Optimal dimensions for dressings *E* are shown.

provides an excellent tract for the entry of microorganisms If there is undue malodor increased pain or an unexplained elevation of temperature the dressing should be changed

A dressing change should be performed under sterile conditions *preferably in an operating room It must be carried out slowly and* painstakingly in an effort to be as gentle as possible If the dressing is moistened before the innermost layers are removed there is less pain and trauma to the area It is important to obtain the confidence of the patient so that he is cooperative during the uncomfortable dressing change Anesthesia should be avoided but this is not always possible Frequent anesthesia for change of dressing only adds to the systemic insult in extensive burns and places a greater burden upon the patient s already decreased reserves. Many dressings can be changed with the aid of intravenous morphine analgesia Nitrous oxide and oxygen analgesia may be quite beneficial Intravenous procaine is of little benefit.

Local Antibiotics

The local application of an antibiotic at the time of the initial dressing has been advocated for many years by Colebrook[10] and Jackson[8] at the Birmingham Accident Hospital in England They use penicillin cream made by incorporating 1,000 units of penicillin in a gram of Lanette wax This cream is applied liberally over the burn and surrounding skin with a sterile spatula and covered with a fine mesh gauze absorptive dressing. More recently, they have added polymyxin B (0 1 mg per gram in the same base) and have shown it to be of prophylactic and therapeutic value against *Pseudomonas pyocyanea* (*Ps aeruginosa*)

Although it would appear that the wound might be sterile immediately after burning there is ample evidence to the contrary (see Chapter 7) Cultures taken from burned skin after cleansing may not reveal any bacterial growth, but the microorganisms that normally reside in the crypts of the skin are not killed and proliferate rapidly amid the devitalized burned tissue It remains to be seen whether or not the use of antibiotics applied locally will prevent contamination of the burned surface from the air The routine use of expensive antibiotics for initial dressing hardly seems warranted at the present time It is advisable that the initial dressing of a burn be carried out with lightly impregnated petrolatum fine mesh gauze, or dry, fine mesh gauze and that at subsequent dressing changes, local use of an antibiotic may be indicated if clinical infection is present.

The choice of antibiotics depends upon the sensitivities of the bacteria cultured from the burned surface Antibiotics applied locally seem to be effective for only about 48 hours since they are absorbed into the circulation and into the dressing. Therefore, if maximum benefit is to be achieved from the local application of antibiotics, dressings must be changed every other day

Functional Positioning

It is essential to position injured parts properly in order to gain the best possible recovery of range of motion of joints after prolonged periods of immobilization Proper positioning must be started immediately after injury and maintained until skin coverage is nearly complete Because of contracture, certain positions of immobilization seem best for burned patients. In many instances these are not necessarily the same as those described by the orthopedic surgeon as ideal for ankylosis of the joint

The neck is kept in as extended a position as it can be held without undue discomfort The trunk and hips are maintained in an anatomic position Almost complete extension is advised for the knees, re-

gardless of the location of the burn The ankles are maintained in flexion to 90 degrees to prevent shortening of the Achilles tendon The shoulders must be maintained in an anatomic position except in burns of the axilla which require immobilization with the arm in 90 degree abduction A position of about 140 degrees of flexion is suggested for the elbow If there is a burn of the antecubital fossa in which there is danger of contracture in partial flexion complete extension of the elbow is indicated

The metacarpal phalangeal and interphalangeal joints of the thumbs are kept in approximately 15 degrees flexion The thumbs are abducted to maintain the breadth of the web space

The metacarpophalangeal joints of the fingers must be immobilized in almost 90 degrees of flexion This prevents contracture of the collateral ligaments and maintains length of skin over the dorsal surface of the joint. The proximal interphalangeal joints of the fingers are immobilized in 30 to 45 degrees of flexion The wrist is extended

THE EXPOSURE METHOD

In 1949 Wallace of Edinburgh reintroduced the exposure method of local care [22] After Pulaski had visited Wallace s clinic he initiated an investigation concerning the exposure method in the United States Blocker was stimulated by Pulaski s interest and since that time the exposure method has been evaluated in many clinics [3, 5, 6, 7, 16, 17, 1]

The earliest American reference to the exposure method is in an article by Copeland published in 1887 [12] Sneve gave an excellent detailed description of exposure of burns in 1905 and set forth a summary that closely parallels present-day concepts of the use of this method [19] Soon after its introduction exposure was combined with heat and rapidly fell into disrepute

The accepted technique for the exposure method includes initial cleansing of the burn wound and placing the patient in bed on clean, nonsterile sheets in the most comfortable position that completely exposes the affected areas The exudate of a partial thickness burn dries in 48 to 72 hours and forms a hard crust that serves as a natural protective cover for the wound Epithelial regeneration proceeds beneath this crust and is usually complete in 14 to 21 days. The crust then falls off spontaneously and leaves behind a nonscarred healed surface (Fig 22)

The evolution of a full thickness burn treated by exposure is different Surface exudation is minimal if present at all and crust formation does not occur Instead the pearly white or charred dead skin dehydrates and is converted into an eschar in 48 to 72 hours after

FIG. 22. *A* Second-degree burn treated by exposure. This patient was burned when a gas stove exploded. The second-degree, burned areas over the left shoulder arm and left side of the chest have been cleansed and all detached epidermis removed. A plasma-like exudate is exuding from the injured surface.

B The 9th postburn day A firm, natural protective covering of the wound has formed from the drying of the exudate Some of the superficial areas on the left side of the face and front of the chest have completely epithelized The band of normal skin on the left forearm was uninjured be cause of protection from a wrist watch With a burn on only one side of the body this patient was ideal for treat ment by exposure.

C The 19th postburn day The entire crust has desquamated leaving a well epithelized surface. There is reddening and diminution of pigment over the burned areas on the face, left arm and left chest but there is no evidence of scarring.

exposure This eschar serves as a temporary physiologic cover until liquefaction occurs beneath it in 12 to 21 days (Fig. 23)

The term eschar" refers to the dead tissue of a full thickness burn whereas the term crust should be reserved to designate the firm cover over an exposed partial thickness burn which is composed principally of dried exudate The term slough is often used as a

FIG 23 *A* Evolution of a third-degree burn treated by exposure. This 34-ye white male rancher experienced full-thickness burns of both lower extremities and (40 per cent of the body surface) when his clothes caught on fire while cleaning a tr The area was cleansed and exposed The thrombosed vessels of the lower leg and *eschar are evidences of full-thickness injury These circumferential burns were ex by turning the patient every two hours on a Stryker frame*

B The 14th postburn day The eschar has darkened and some areas about the are beginning to loosen.

C The 30th postburn day The eschar loosened by liquefaction beneath and trimmed away by cutting the collagenous bands that place. The deep de burn around the knees ha epithelized. T area is a clean, ulating surface ready fo

synonym of 'eschar Slough refers to a moist eschar that is in the process of being sequestrated from viable tissue

Once the burned surface is dry all efforts must be directed toward avoiding injury to crusts or eschars Cracks are ready avenues for invasive bacteria If infection occurs the protective covering surrounding the cracks becomes lifted from the underlying tissue and it must be trimmed away If the open area is covered with a piece of moist fine mesh gauze, a new crust will form If suppuration is spreading, crusts or eschars must be removed and dressings must be applied

Since crusts are formed from drying exudate they tend to be elevated above the intact skin Deep dermal burns—whose exudate is characteristically scanty—form smooth crusts that are level with intact skin Eschars shrink because of dehydration and, as a consequence are depressed below the intact skin

The temperature and humidity of the environment have considerable influence on the time the crust or eschar may be formed A dry environment hastens the formation of the protective crust. In some instances, this can be aided by the use of a fan, but drafts cause discomfort and should be avoided in the early hours after exposure.

The crust over a superficial second-degree burn desquamates in 10 to 20 days, the time depending upon the depth of the injury In deep dermal burns, the crust tends to be thicker and to remain adherent for 21 to 30 days. In third-degree burns, liquefaction of the dead tissue may occur beneath the eschar These areas of softening may be outlined by palpation When softening occurs, the eschar is ready for removal and granulating tissue is seen beneath the softened area However the eschar of a full thickness burn usually remains firmly attached to the underlying tissue for 21 to 25 days As soon as it begins to loosen, the collagenous bands are cut and the area is completely débrided

Treatment by exposure ends in partial thickness burns when the protective covering falls off and complete healing has occurred It ends in full thickness burns when eschar removal has been achieved *Granulating surfaces should never be exposed* except in the late care of burns after grafting when only minute areas of granulating tissue remain between grafts Since deep dermal burns may require a long time for complete healing, a decision must be made as to when removal of the protective covering is to be carried out If there is no

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D The 88th postburn day All wounds have been completely covered by split thickness sheets of skin. Three grafting procedures were required. The patient was ambulatory and discharged from the hospital at the time this photograph was taken. There is still evidence of edema in the feet and legs. Rubberized elastic bandages were worn on the legs for six months.

associated full thickness injury, deep dermal burns may heal spontaneously in 30 to 35 days providing the covering remains intact In general however if there is evidence of full thickness involvement the covering of the deep dermal area must be removed in 26 to 28 days and a skin graft must be applied.

The success of the exposure method depends almost entirely on how adequately complete exposure and immobilization of all burned areas can be achieved Elevation hastens fluid absorption and should be used if possible unless it causes undue discomfort

Technique of Exposing Various Areas

The technique of exposure may be different in every patient because different configurations of the burned surface pose individual problems Much of the success of exposure depends upon the ingenuity of the surgeon and nursing staff in achieving a good protective cover This protective cover must be managed in such a way as to prevent softening and maceration or cracking

Burns of the face are easily exposed (Fig. 24) Because of the good vascularity of the face rapid healing of partial thickness burns occurs and eschars sequestrate early In full thickness burns removal of eschar may be hastened by application of saline soaks beginning on the eighth to tenth day

Burns of the anterior aspect of the neck should be positioned with the neck in extension Sandbags placed at the side of the head aid immobilization In almost every instance cracks will occur in the region of the thyroid cartilage because of deglutition Fortunately these cracks are rarely troublesome because the excellent blood supply of the neck promotes rapid healing. Wallace has designed a crucifix splint that facilitates extension and immobilization in children [16]

Burns of one side of the upper extremity can be easily exposed Burns that are circumferential are more difficult to position If the burn is limited to the forearm the palm may be allowed to rest on an object that elevates the volar aspect of the forearm and permits complete exposure If the entire arm is involved in a circumferential burn it may be necessary to turn the patient frequently allowing one side to dry and then placing it on a fine mesh gauze absorptive dressing and allowing the opposite side to dry This requires considerable nursing attention but a good protective covering will usually form in 72 to 96 hours

In burns limited to the hands exposure is quite easy The patient can usually be encouraged to keep his hand in a position of function for the first 48 hours until a firm protective covering is formed Thereafter motion of the hand will be limited because the crust or

FIG. 24 *A* Second-degree burn of the face treated by exposure. This patient received second-degree burns over several exposed areas of the body after an explosion of natural gas. The immediate treatment consisted of cleansing the face and applying a bulky dressing. The eyelids were sutured together On transfer 24 hours later the face was exposed. The eyelid sutures were removed and remaining blisters were cut away

B The 15th postburn day A good crust formed from the plasma exudate, and in the more superficial portions of the injury over the forehead part of it has desquamated. The remainder of the burn crust is beginning to loosen as epithelization occurs beneath it. All of the initial edema of the face has disappeared

C The 35th postburn day At this time, the patient was discharged with complete epithelization of the face and no evidence of scarring. A few small crusts from deeper burns remain on the right ear

eschar serves as a splint If the volar surface of the wrist is burned, many patients fail to keep the wrist extended and let it drop into flexion This is undesirable but it seldom causes functional impairment.

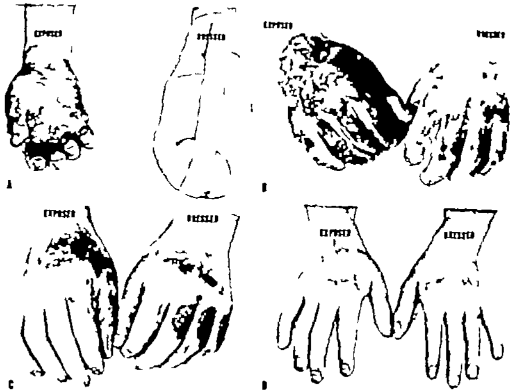

FIG 25 *A* Comparison of occlusive dressings and exposure. This young white male had comparable partial thickness burns of the hands and a partial thickness burn of the face from a gasoline explosion Both hands were cleansed and all detached epithelium was removed. The left hand was dressed with petrolatum-impregnated gauze and put in a position of function The right hand was exposed This photograph was taken 30 hours after injury and shows the drying of the exudate that seeps from the exposed wound.

B The 9th postburn day The dressing was removed from the left hand and there is no evidence of infection. A good protective crust has formed on the right hand without evidence of infection. During the first two days after injury the patient stated that the dressed hand was more comfortable but thereafter he thought the right hand was more comfortable. At the termination of treatment, he stated that he preferred exposure because of the pain during the dressing change

C The 23rd postburn day There appears to be comparable healing of both sides. A few areas on the dorsal aspect of the fingers of the left hand were slightly deeper than other areas. These areas healed uneventfully

D The 65th postburn day This photograph was taken at the time of follow-up examination. There is some discoloration of the dorsum of both hands but no scarring Both sides healed equally well. Range of motion returned to normal at approximately the same time.

Motion of the fingers and wrist before a burn wound is completely healed is apt to lead to disastrous results by cracking the protective crust particularly over joints Motion must not be encouraged until epithelization has occurred Immobilization of the hands for as long as three weeks results in no permanent impairment of function Most partial thickness burns have healed by this time and eschars of full thickness injury must be excised Blocker prefers to apply absorptive

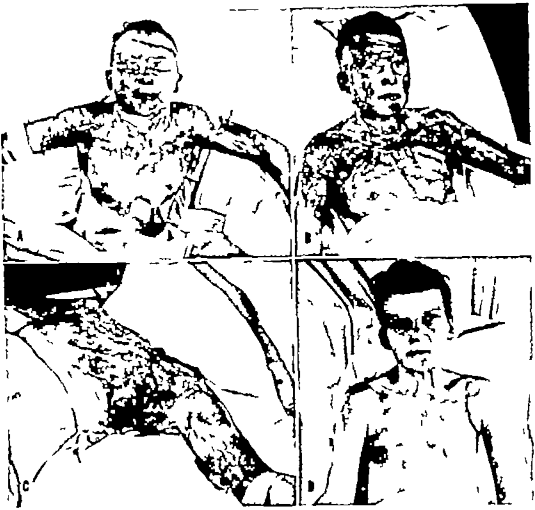

FIG 26. *A* Third-degree burn of one side of the body treated by exposure This middle-aged white female sustained a full-thickness burn over the anterior chest and upper arms and partial-thickness burns of the face when her nightgown caught on fire. At the time of this photograph four days after injury she was exposed and showed early eschar formation over the chest. There was considerable edema of the area.

B. The 14th postburn day A good eschar protects the burn wound from invasive infection. The patient is comfortable and eating well. Some of the partial-thickness burn of the face has completely healed. On this day she was taken to the operating room and the eschar was excised.

C The 14th day This photograph was taken on the operating table at the end of excision of the eschar over the chest and upper arms. A large absorptive dressing was applied and skin grafting was carried out four days later

D The 50th postburn day Complete healing has occurred and the patient is ready for discharge from the hospital. Thick split thickness grafts have been applied around the axilla.

dressings for 48 hours before exposing hands He believes that this helps to establish and maintain a good position [7]

Burns of the lower extremity frequently extend from the gluteal folds to the ankles The feet and ankles are almost always spared Adequate elevation and exposure may be obtained by placing the feet on several blankets If this does not expose the burned surfaces

adequately it may be necessary to place the patient on a Stry frame and expose first one side and then the other turning every hours until a good protective cover has formed

Burns involving only one side of the trunk are particularly suited for treatment by exposure (Fig. 26) Many burns of the tr are of such configuration that they are difficult to expose. Encirc burns must be exposed on a Stryker frame It is possible to obtai good protective covering on one surface, while the other surface r on a fine mesh gauze dressing. By turning the patient every two ho a fairly good protective covering will form Circumferential part thickness burns of the trunk heal well after such treatment I difficult to prevent suppuration in encircling full thickness burns

Burns of the perineum are difficult to expose properly and dry is rarely seen Some suppuration is almost inevitable, but fortunat the skin of the perineum possesses a great capacity for regenerat and spontaneous healing occurs even in the presence of minimal fection Eschars in this area become moist and they must be remo as early as possible

Rationale of Exposure

Successful treatment by the exposure method seems inconceiva at first thought Abundant clinical observations however have de onstrated that partial thickness burns—when treated properly exposure—heal uneventfully beneath the protective covering of crust If kept dry, the dead skin of a full thickness burn seems serve as an excellent cover for the wound and to protect it from vasion by bacteria

In contradistinction to mechanical wounds the local injury of t burn is primarily a wound of area and extent rather than of dep This may explain the effectiveness of the exposure treatment of bur Free drainage is always present in partial thickness burns unless it blocked mechanically The excellent drainage of such a burn cannot duplicated in any other wound Because of this drainage only a th layer of exudate can cover the large surface at any one time As a r sult much of the exudate is exposed to the air at all times Evaporati and drying are thus promoted

It is not known how crust formation occurs without infectio However when bacteria are transplanted to a new environment the is a preliminary period in which certain bacteria die off and others f to multiply In their effort to adjust metabolically to a new enviro ment bacteria are thwarted by what happens on the exposed burn surface the exudate dries and the bacteria are subjected to an enviro ment that is cooler than body temperature Drying is a deterrent

bacterial reproduction Although contaminating microorganisms may be present in abundance on the burned surface, their proliferation is hindered and the dried cover prevents invasive infection

In most burned patients, antibiotics are given prophylactically Penicillin diffuses freely into the exudate of recent burns As drying of the exudate proceeds, the concentration of penicillin on the burned surface actually increases, and it is likely that the fully formed crust has a considerable quantity of penicillin incorporated in it In burns of minor extent, however, a noninfected crust forms even when chemotherapeutic agents are not administered

The eschar of a full thickness burn is composed of dehydrated dead skin As long as it remains dry it appears to be an effective barrier against invading microorganisms Since bacteria around the hair follicles and in the sweat glands remain viable in many full thickness burns a certain amount of infection always occurs beneath the eschar It must be remembered that eschars are dead skin and should be removed (see Chapter 7)

COMPARISON OF THE OCCLUSIVE DRESSING METHOD AND THE EXPOSURE METHOD

There seems to be a close relationship between occlusive dressings and exposure because both techniques accomplish many of the aims in local care Too frequently the exposure method is labeled as an open method' of treatment in contradistinction to the occlusive dressing that has been referred to as a closed method The dry protective covering that forms over an exposed burn certainly effects excellent temporary closure of the wound Wallace has rightly condemned the use of the words open" and closed because he believes that the coverings that form over exposed burns constitute effective barriers against contaminating microorganisms He further points out that when occlusive dressings become moist, they are 'open" to contamination [20] If a burn is not properly exposed and a protective barrier does not form, it certainly is "open ' to invasive bacteria In such an instance the exposure method is used improperly and should be more appropriately termed ' neglect "

Neither method is ideal Both have certain advantages and disadvantages The occlusive dressing method is applicable to all areas whereas certain burns may be of such configuration that adequate exposure cannot be achieved Under such circumstances, it may be wise to expose some areas and dress others on the same patient Burned surfaces that have been dressed may be exposed, but it is probably not wise to use the exposure method on areas where dressings have been applied for more than four or five days. Pulaski re

ported that good results were achieved when initial cleansing a dressings were applied and exposure carried out as long as eight d later [17]

One of the chief advantages of exposure seems to be its effect control of infection The warm, moist, dark environment beneath dressing is conducive to bacterial growth This occurs most often warm humid climates Deep dermal burns treated by exposure become dry and usually heal uneventfully however when treated dressings they frequently become infected and are converted to fu thickness injury Exposure permits constant observation of wound and any infection which may occur can be detected earlier

During the first 48 hours after exposure patients have pain a complain of chilling, but they are quite comfortable after the cr has formed They have less discomfort if drafts are avoided and if t ward is kept at an even temperature When dressings are applied im mediately after the burn there is no pain and the patient is co fortable After a few days however patients who had their woun dressed have more fever and complain of greater discomfort th those who have had their wounds exposed Offensive odors may associated with a dressing, and they hinder the appetite and low morale

Dressings permit better immobilization than exposure The exa depth of the burn can usually be ascertained earlier when the dressi method is used than when the burn is exposed This undoubtedly pe mits excision of the eschar a few days earlier Evans felt that separ tion of burn slough was more rapid when dressings were used [14]

In the moderate-sized burn there is little difference in the nursi care required following the use of the two methods In very extensi burns particularly when exposed patients must be turned on Stryk frames and the nursing care of the exposed burn is increased co siderably On the other hand, the exposure method eliminates th necessity of frequent dressing changes by the physician Undoubtedl this fact points out one of the advantages of exposure in extensiv burns that is rarely recognized The detrimental effect of frequer anesthesia on a severely injured patient is well established In majo burns of from 40 to 60 per cent of the body surface an anesthetic i almost invariably required for a dressing change Dressing change may be necessary at two- or three-day intervals to keep the woun surface clean dry and free from suppuration In such instances th frequent administration of anesthesia is deleterious to the conditio of an extensively burned patient. When exposure is used no anestheti is necessary until the eschar is finally removed In fact some ex tensively burned patients may be almost completely debrided i

stages without anesthesia, if the eschar is allowed to remain until liquefaction occurs beneath the dead skin

Although burned patients who are exposed can be transported without serious deleterious effects, the associated discomfort and danger of additional contamination make dressings preferable Burned patients who are treated on an outpatient basis must be dressed, otherwise trauma may crack the protective cover In addition, the unsightly appearance of the burn and the protection necessary to the crust may interfere with the activities of an ambulatory patient.

Since exposure is applicable only to burns and not to any other wounds, the coexistence of soft tissue wounds and burns at the same site contraindicates exposure Exposure eliminates the need for elaborate aseptic technique and extensive dressings. It would certainly be the preferred method of local care if a large number of casualties were to be treated

There seems to be little difference between the use of exposure and dressings in the treatment of burns of the hands A better position is possible when a dressing is used and a patient is permitted greater freedom of movement However the patient usually prefers exposure because he has real dread of the pain associated with even the gentlest dressing change. Evans believed that the exposure method gave very poor results when used on a burned hand Resulting dysfunction in every case was more than he would have expected with dressings Deleterious hyperpyrexia was less with exposure [14]

In some uncooperative patients where positioning is difficult, or in patients who persist in picking at the crust thereby causing infection, exposure is contraindicated

Almost all partial thickness burns do extremely well when treated by exposure This method is certainly preferred for burns of the face burns of the perineum and burns of one side of the body

In deciding on the method of local care to be used, the surgeon should keep in mind the primary aims of local care He should select the method for each individual patient in accordance with his experience and the exigencies of the situation Both methods may be used in treating the same patient and one should be used to complement the other

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CHAPTER 5

Repair of Full-Thickness Burns

ONE OF THE MOST important facets in the repair of the full thickness burn is an aggressive approach to the burn wound This means that the dead tissue must be removed as expeditiously as possible and skin coverage must be achieved with the least possible delay In the normal evolution of the full thickness burn wound, the eschar begins to loosen from the underlying tissue between the 14th and 21st day This period is commonly known as the sloughing or autolytic stage and is invariably accompanied by suppuration As the dead tissue loosens, granulation tissue forms beneath the eschar The sooner this eschar is removed, the less the suppuration and the earlier a graft can be applied to close the wound

REMOVAL OF ESCHAR

The problem of removal of eschar has been the subject of continuing research Various chemicals and enzymes have been suggested as methods for hastening dissolution of the eschar At the present time there is no easy, rapid way to remove the dead tissue of a third-degree burn In areas that have been treated by repeated dressings the eschar softens and bacterial activity beneath the eschar seems to have some effect on its sequestration The dehydrated firm eschar seems to remain firmly attached in areas treated by exposure until about the time when the surrounding partial thickness burn is healed When the eschar begins to loosen purulent material is frequently found beneath it Several tough strands of collagen seem to keep the eschar attached to the underlying subcutaneous tissue for a few days.

The easiest and quickest method for removal of eschar is excision On the first to the third day after a burn, excision is an acceptable procedure when the full thickness injury can be definitely delineated

providing its extent is not too great. This procedure of *immediate excision* will be discussed in some detail later in this chapter. After the burn has been exposed or dressed for a period of ten to eighteen days, a pronounced inflammatory reaction is present around the injured area. If a third-degree burn wound covers a large extent of the body surface, it is usually unwise to attempt surgical excision through this inflamed tissue. Lymph and vascular channels may be opened to widespread infection, causing septicemia. In small wounds that remain relatively clean, however, surgical excision may be carried out at about the time the surrounding partial thickness burn has healed.

There are three acceptable methods for removal of eschars: (1) repeated change of dry dressings, (2) wet soaks, and (3) surgical excision.

In burns that are dressed, the initial dressing usually remains in place from five to ten days. Thereafter the dressing is changed about every five days. *This repeated change of a dry dressing* helps to keep the area clean and provides adequate drainage. At the same time the eschar becomes soft and begins to loosen. When the eschar reaches the sloughing stage, more frequent changes of dressing aid in draining the wound and in keeping it clean. In exposed burns the full thickness eschar begins to loosen and crack about the 14th day. At this time dressings must be applied to prevent invasive infection. As they are changed every four or five days, a certain amount of dead tissue is removed at every dressing change. This repeated change of dry dressings allows for natural sequestration of the eschar. This method of eschar removal requires a longer period, however, than wet soaks or surgical excision.

If the area of full thickness injury is of such configuration that *wet saline soaks* can be applied and changed every four hours, soaks may be used to hasten removal. The wet dressings keep the eschar soft and, when they are changed, any loose areas of eschar are removed. If there is an appreciable amount of cellulitis and infection around the wound, the wet-soak method is certainly desirable.

At the time of dressing change it is advisable to remove only the portion of the eschar that is loose. Forceps are employed to remove the dead tissue and scissors are used to cut the collagenous bands that attach the eschar to the und[illegible] ibcutaneous ti[illegible] sharp dis section is used to excise are[illegible] cause bleedi[illegible] y break down certain barriers again[illegible] infection [illegible] et soaks seem to be a good method [illegible] ng the esc[illegible] st be remembered that this method [illegible] ming. A t[illegible] amount of m[illegible] re is required to [illegible] gs prope[illegible] schedule.

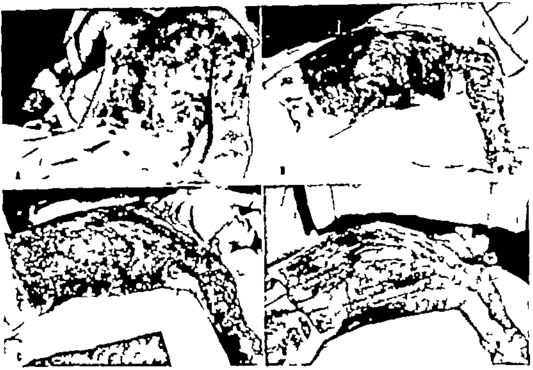

FIG 27 *A* Third-degree burn of chest and left arm sustained when mattress caught on fire.

B The 16th postburn day Area has been exposed and there is a firm, protective eschar over the surface.

C The 16th postburn day The eschar has been excised under general anesthesia. All bleeding points have been ligated and the surface is ready for a dressing. Grafting was carried out four days later

D The 46th postburn day All grafts have taken and the patient is ambulatory

Gentleness is essential in making a change of dressing and care must be exercised in removing all soft and loose pieces of sloughing eschar

Wet soaks may be applied by incorporating catheters into a large bulky dressing and dripping saline through the catheters This is an easy method but it does not hasten the removal of eschar nearly as rapidly as changing the gauze pads every four hours

The quickest method for removing an eschar is *surgical excision* When a full thickness eschar is excised, grafting can be carried out earlier (Fig. 27) Excision causes little added stress to the patient if the burn wound is not extensive. In burns involving less than 15 per cent of the body surface, surgical removal of the eschar is an accepta ble procedure

Surgical removal has some serious disadvantages. It may open avenues for invasive infection If the patient has suffered extensive burns excision is a formidable procedure entailing general anesthesia and considerable blood loss and it may predispose to a breakdown of the body s defense mechanisms against infection

Excision may be undertaken as soon as the full thickness injury

FIG 29 *A* This 11-year-old boy sustained burns over the chest, arms, neck, back and legs, totaling 45 per cent of the body surface, 35 per cent being third degree.

B The deep third-degree burn extended over a large portion of the back.

C About 46 hours after injury the patient appeared in good condition and was taken to the operating room where the full thickness areas of the chest neck back and right arm were excised. The skin and subcutaneous tissue of 30 per cent of the body surface was excised. A dressing was applied.

D Three days after excision, autografts were used to cover about one-half the open area. Homografts were used to cover the remaining areas. This photograph was taken at the first dressing change 10 days following injury The grafts were put on by the lay-on method They were not sutured in place but held by a firm dressing As the homografts disappeared, the areas were covered by autografts.

E The 45th postburn day All the areas have healed completely It was necessary to graft moderate areas of the inner aspect of each thigh. The patient s nutrition was maintained by intragastric tube feedings.

F The appearance of the back on the 45th postburn day The patient is ambulatory and ready to be discharged from the hospital. Immediate excision shortens the hospital stay However excision of such large areas is a formidable operation and required a highly specialized team of surgeons.

Immediate excision of small, well-delineated full thickness areas has been a well-established procedure for many years [9] More recently advances in replacement therapy have made it possible to excise larger areas Immediate excision is indicated when the third degree burn is readily identified and the extent of injury does not exceed 20 per cent of the body surface (Fig 28) In some instances it may be possible to excise larger areas but such a procedure is difficult and requires a highly specialized team of surgeons (Fig. 29)

In certain areas of the body excision is definitely indicated Full thickness burns of the hands heal more quickly if they are excised soon after injury (see Chapter 6) Because it is most difficult to determine areas of full thickness injury on the face and because of subsequent disfigurement, initial excision of facial burns is rarely indicated

When immediate excision is elected adequate replacement therapy must be assured The dead skin and subcutaneous tissue are removed down to the underlying fascia If only the skin is excised, the underlying fatty subcutaneous tissue may slough because of thrombosis of the vessels and leave an inadequate barrier against infection and a poor surface for grafting. Since it is quite difficult to judge viable fatty tissue beneath a full thickness burn, the safest procedure is to remove all tissue down to the fascia

Some surgeons prefer to apply a skin graft immediately after excision In most instances, this procedure is not as desirable as applying a dressing and delaying skin grafting for two to five days Such a delay gives the surgeon an opportunity for a second look to make sure that all the dead tissue has been removed If grafting is carried out immediately after excision, bleeding beneath a graft may cause a poor take Delay before coverage also permits the formation of small, granulating buds, thereby decreasing the incidence of infection and enhancing the take of the graft.

Immediate excision requires a certain degree of courage and judgment on the part of the surgeon The procedure is most gratifying, however as it eliminates the dead tissue and permits the application of a skin graft within four or five days after injury The patient s rehabilitation can be well under way by the end of the third or fourth week and the period of hospitalization is decreased

One of the pitfalls of immediate excision is the frequent error in judgment concerning the extent of the full thickness wound. If all of the third-degree burn is not removed the edges surrounding excision and grafting will become infected and may cause partial slough of the graft In most instances, it is advisable to excise generously and to make sure of the complete removal of all the full thickness burn.

PREPARATION OF THE RECIPIENT SITE

The aim in preparing a recipient site for grafting is to obtain a wound surface on which an optimum graft take may be expected

It is almost impossible and certainly *unnecessary to sterilize a* granulating surface for a good graft take If the amount of purulent material and bacterial proliferation is minimal however a graft will usually take unless the surface is contaminated by group A beta hemolytic streptococci When a large amount of purulent material caused by any bacteria is present, the graft may not adhere to the underlying surface

Several methods may be employed to prepare the recipient site for grafting. Frequent changes of dry dressings will achieve the desired *result in most instances Cultures of the wound must be taken to make* sure that beta hemolytic streptococci are not present Simultaneously the flora of the wound should be identified as well as the sensitivities of the various microorganisms that colonize it

An excellent method for cleansing a wound and preparing it for grafting is the application of wet dressings that are to be changed three or four times a day They afford good drainage to the wound and decrease the bacterial inoculum The wet-dressing method however, is time consuming and it requires meticulous nursing care.

Another method for preparing the recipient site for grafting is by the application of local antibiotic ointments This method offers several advantages It usually assures the absence of any beta hemolytic streptococci and it also diminishes the bacterial flora on the wound surface Several chemotherapeutic agents are available and the appropriate one is dictated by the sensitivities of the bacteria that *colonize the wound Local antibiotics are of greatest value when they* are applied at two-day intervals (see Chapter 7)

The chief disadvantage of chemotherapeutic agents is the cost. They are indicated in dirty wounds however *where rapid cleansing* of the surface can be achieved by their use

If wet soaks are used to remove the eschar it may be that the surface is ready for grafting as soon as all the dead tissue is eliminated Most areas may be prepared for grafting by frequent changes of dry dressing, thus carrying out good wound toilet Under such circumstances it is advisable to apply an antibiotic ointment two days prior to the grafting procedure

Wound cultures should be obtained at frequent intervals Grafting should not be attempted *on wounds infected by group A beta hemolytic streptococci* These microorganisms cause graft failure and must be eliminated before grafting If streptococci are present the preferred method of treatment is systemic penicillin or tetracycline combined

with an antibiotic applied locally Details of antibiotic therapy in the grafting stage are discussed more fully in Chapter 7

When grafting has been delayed soft, pale, heaping granulations are often present Skin does not take well on such granulations They must be shaved down to the base and a dressing applied for two days If grafts are applied immediately after shaving the granulations, hematomas will form beneath the grafts and cause a poor take Sometimes when there is a considerable amount of fibrous tissue beneath old granulations, it is advisable to excise the entire area down to fascia It is not infrequent to observe a poor take of grafts in old burns because of the diminished blood supply to the area due to the fibrosis that has developed beneath the unhealed wounds In such instances it is desirable to excise the entire area, apply a dressing, and then graft a few days later (Fig. 30)

PLANNING THE GRAFTING

A tentative time schedule should be arranged to enable grafting to be carried out rapidly and expeditiously In general the earlier the grafting, the better will be the take and the less the morbidity As the eschar is being removed and the recipient site prepared a patient must be kept in the best possible nutritional state, blood transfusions are given in an effort to maintain the hematocrit at 45 or above The extent of any one grafting procedure is determined by the general condition of the patient, the available donor areas, and the experience of the surgical team who carry out the operation

Some surgeons favor restricting the grafting procedures to approximately one hour This practice limits the amount of grafting that can be performed per operation and makes several grafting procedures necessary It appears that burned patients who are maintained in a good state of nutrition and who have an adequate blood volume will tolerate an operation lasting three or four hours Since grafts take best in the early postburn period plans should be made to cover as much of the burn wound as possible at the first grafting procedure If a patient is extensively burned, it is advantageous to have three or four surgeons assist in the transfer of skin When such a patient s condition is endangered by a serious threat of infection available autografts may be used to cover a large area of the wound and the remainder of the granulating surface is covered with homografts

Priority of Areas for Skin Coverage

Certain areas of the body should be given consideration for coverage before others (Fig 31) Areas around joints are covered

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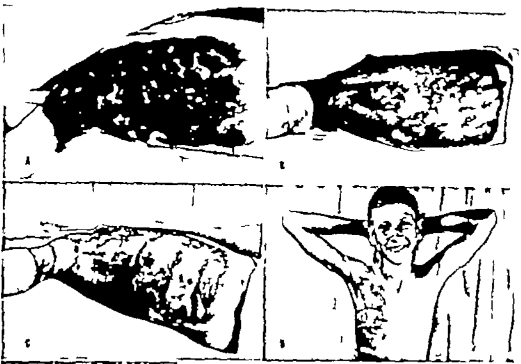


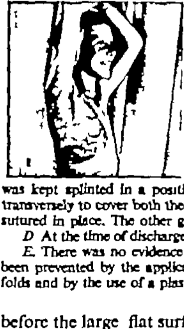


FIG 30 *A* This 12 year-old boy had been burned 10 weeks prior to the time of this photograph. Several attempts had been made to apply grafts but takes were poor Heaping granulation tissue was present and it bled easily

B. The entire area, including the axilla, was excised down to the fascia. This removed the bulky granulations and the fibrotic scar beneath. A dressing was applied and grafting was carried out four days later

C A good graft take was achieved. The right arm was kept splinted in a position of abduction. The grafts in the axilla were placed transversely to cover both the anterior and posterior axillary folds. These grafts were sutured in place. The other grafts were applied in lay-on fashion.

D At the time of discharge, the patient had good movement of his right arm.

E. There was no evidence of contracture in the axilla. Limitation of motion had been prevented by the application of skin across the anterior and posterior axillary folds and by the use of a plaster splint to keep the arm in abduction.

before the large flat surfaces Priority of areas for skin coverage is as follows hands and face first, with special priority to the hands then areas of motion especially those about the elbow It is wise to obtain skin coverage of the arms and hands as early as possible This procedure permits the patient to feed himself and improves his morale When a leg is burned the area around the knee should be covered first Next in order of preference is the anterior aspect of the lower leg, followed by the posterior aspect of the lower leg. The thighs may wait until later An attempt is made to cover the areas of motion in order to lessen fibrosis and scarring which may interfere with func

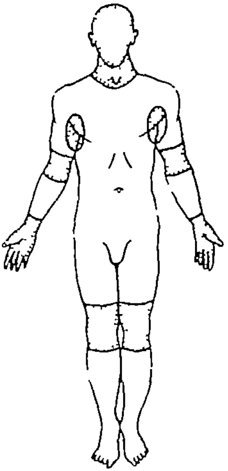


Fig 31 Priority areas for skin coverage. The hands and face must be given the highest priority for skin coverage. Areas of motion such as the axilla, elbows, and knees should be covered early to prevent contracture and to allow for early return of function.

tion It is usually difficult to obtain a good take around the perineum Hence this area should be given lowest priority

Selection of Donor Sites

The easiest and most accessible area from which to take skin is the anterior aspect of the thigh A large quantity of skin may be obtained rapidly from this area by using an electric dermatome The next most accessible area is the anterior trunk

Selection of a donor site is usually determined by the distribution of the areas to be grafted For example, if the entire recipient site area is on the posterior aspect of the body and donor skin is obtainable from the posterior aspects of the legs and back, then these areas are selected Selection of a donor site is also partially determined by the method of treatment of donor sites The selection of donor areas may differ somewhat depending upon whether or not all donor areas are treated by exposure or by dressings When there are circumfer-

ential burns of an appreciable area it is advantageous to cover the anterior wound with skin taken from donor areas on the anterior surfaces of the body at the first grafting procedure. Then the patient may be turned on a Stryker frame and skin from the posterior aspect of the body may be utilized to cover recipient areas on the back at a later procedure.

Several crops of skin must be taken from the same area if a patient has extensive burns Depending on the thickness of the skin a second crop can be removed approximately three or four weeks after taking the first skin The thinner the donor site is cut, the more rapid is the healing of the area and the earlier a second crop of skin may be removed

The skin over the tibia should be avoided whenever possible If there is a choice between using the chest and the abdomen the chest is preferred because donor sites in this area are less painful than those on the abdomen If the donor areas are to be treated by exposure, the anterior aspect of the body is preferred to the posterior aspect because it permits a patient to lie on his back in a more comfortable position Generally donor areas are selected in this order of preference an terior aspect of the thighs chest abdomen, lateral aspect of the lower leg posterior aspect of the thighs back posterior aspect of the lower legs the arms The determination of donor sites selected is somewhat dependent upon the type of dermatome to be used It is easier to obtain skin from the lower legs and arms with an electric dermatome than with the Padgett dermatome

Large quantities of skin may be obtained from the arms if necessary It is inadvisable to take skin over areas of movement or flexion creases Healing in these areas is delayed because of motion The popliteal area the groin, and the antecubital area should be avoided Sometimes it is necessary to take skin from the dorsum of the foot or the scalp when a patient has extensive burns Under such circum stances, small postage stamp strips of skin may be taken by means of an electric dermatome In extensive burns every donor area available must be used in an attempt to achieve skin coverage

REMOVAL OF SKIN FOR GRAFTING

Although various types of thick grafts and flaps have a place in the reconstruction of deformities following thermal injury they are usually not used to close the wound during the early postburn period [4] Skin is used primarily for rapid coverage This aim was achieved several years ago by the use of pinch grafts. With the various instru ments available at the present time there is probably no need for any type of graft other than a split thickness graft The skin removed is

generally between .010 and .015 of an inch in thickness. The thinner the graft the better the take and the thicker the graft, the better the cosmetic result. If a large, flat surface is to be covered a very thin layer of skin must be taken in order that the donor area may be used again within a short time for a second crop If certain areas of function are to be covered, such as the hand and around a joint then a little thicker graft should be applied It is doubtful if any place other than the soles of the feet require a split thickness graft thicker than .015 of an inch In babies or children a graft must be very thin

A patient is usually given a general anesthetic for grafting When a patient is seriously ill or when he needs only coverage of a small area skin may be taken under local anesthesia It is then placed on the wound and held by a firm pressure dressing.

The donor area selected should be shaved and washed with soap and water Some surgeons prefer to shave this area on the night before the operation It is easier and more comfortable if carried out under anesthesia immediately before the graft is taken There are many ways to prepare the skin but it appears that washing with some type of hexachlorophene detergent or soap is as good as any method

Skin may be cut for grafting by a variety of instruments The type of instrument to be used varies according to the experience of the surgeon One important fact must be kept in mind, however, and that is the sharpness of the blade Regardless of the skill of the surgeon or the construction of the instrument used, a good skin graft cannot be removed by a dull or nicked blade A surgeon must become familiar with the instrument to be used and he must be responsible for the sharpness of the blade Even new blades sometimes may be nicked or dull

When the freehand knife or electric dermatome is used, it is always necessary to have a flat smooth surface Such a surface is hard to obtain in certain areas particularly over the abdomen and chest Whenever the area is irregular it is advisable to inject saline into the subcutaneous tissue in order to make the area smooth This procedure is particularly advantageous if skin is to be removed from a bony chest or a scaphoid abdomen It is also helpful when skin must be taken from the dorsum of the foot This procedure is time consuming if an ordinary 10 cc syringe is used, but large areas can be infiltrated very rapidly with a Pitkin s syringe (Figs 32 and 33) [10]

Brown Electric Dermatome

The Brown electric dermatome is a relatively recent innovation in the field of skin cutting instruments It takes a strip of skin 3 inches in width It is probably the most useful instrument in skin grafting

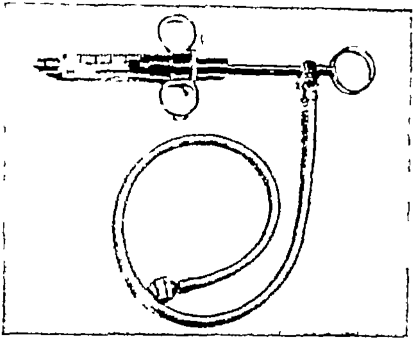


FIG 32. Pitkin's syringe. The free end of the rubber tubing is put in the solution to be injected. The syringe refills as the plunger is withdrawn. This apparatus permits very rapid injections of local anesthetics or saline into the subcutaneous tissue.

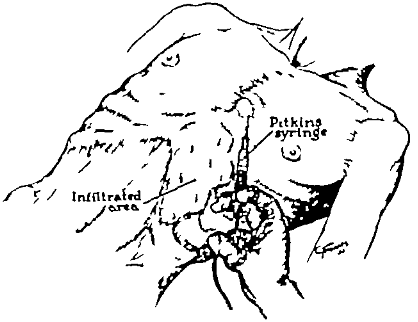


FIG. 33 When skin must be taken from irregular areas with the electric dermatome infiltration of the areas with saline provides a smooth surface for cutting the graft. This is particularly true on the anterior aspect of the chest. Saline is infiltrated rapidly by means of a Pitkin's syringe.

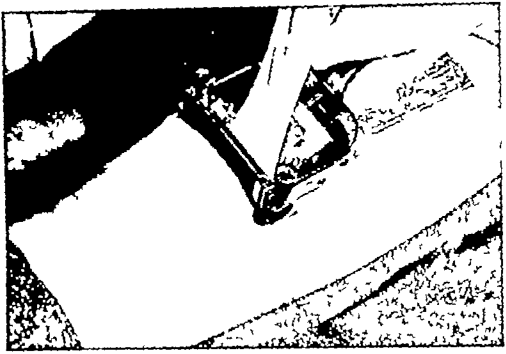


FIG 34 The Brown electric dermatome. Strips of split thickness skin, 3 inches in width, can be obtained rapidly This is the most useful instrument in skin grafting for burns.

for burns because many sheets of thin skin may be removed quickly (Fig. 34) Its construction is simple and little experience is required for the successful removal of a large amount of skin The only real disadvantage in using this dermatome is that a flat firm surface must be available. Such a surface is achieved by using a Pitkin s syringe to inject saline into the subcutaneous tissue (Fig. 33) Sometimes it is quite difficult to take skin from the abdomen by means of an electric dermatome A firm surface may be obtained, however, if the operating table is hyperextended in such a manner that the skin of the abdomen is stretched.

Before any skin is removed the area must be lubricated lightly with mineral oil The dermatome is held in one hand by the handle The thumb and forefinger of the other hand are placed over the two knobs on either side of the instrument In this manner the surgeon can raise or lower the blade and thus obtain firm control in order to exert an even pressure. An assistant can pick up the skin with forceps to enable the surgeon to view the depth of the cut.

The Brown electric dermatome is one of the important recent ad vances in the management of burns A surgeon who is unfamiliar with skin cutting can easily use this instrument and remove large amounts of skin in a short time During extensive grafting procedures, the period of anesthesia is shortened considerably by the use of an electric dermatome. Such an instrument is also valuable in removing

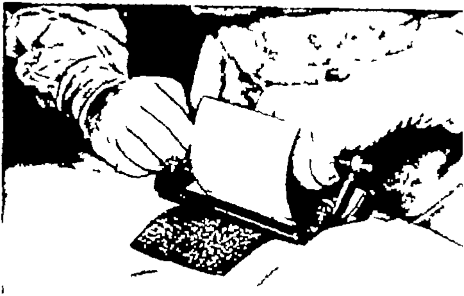


FIG. 35 The Padgett dermatome in action. A full drum of skin measures cm. This dermatome is particularly useful in removing skin for coverage of a motion.

skin from children because of the easy manner in which a ver strip of skin may be cut.

The electric dermatome is particularly advantageous whe moving skin from the arms or from small donor areas such a dorsum of the foot Frequently it is necessary to take small po stamp grafts from limited areas This is particularly true when tient sustains extensive injury Sometimes a razor blade is use removing such grafts but an electric dermatome is much quicke

The electric dermatome has throw-away blades They are goo only a short time and are difficult to resharpen The instrument ever gives good service for several years if it is cared for properl

Padgett Dermatome

The Padgett dermatome a drum type dermatome is particu useful in obtaining grafts from uneven surfaces (Fig 35) This in ment furnishes the best method of cutting skin when a thicker of skin is desired A wider piece of skin can be removed than by an electric dermatome but the piece will not be as long since Padgett instrument cuts an area only 10 x 20 cm The Padgett de tome is particularly useful in removing skin for coverage of hanc areas about joints

A considerable amount of practice is required before this de tome can be used with agility Certain factors must be considered full sized piece of skin is to be obtained All skin oils and any w

remaining after the preliminary preparation of the skin must be re moved This procedure is best accomplished by washing the area with ether and then permitting it to dry

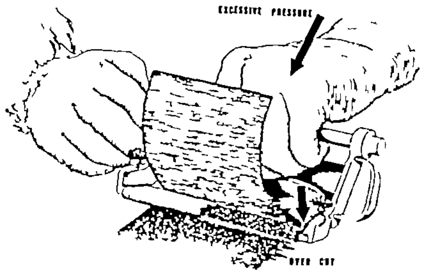
The area to be used as the donor site must be covered evenly with a thin layer of dermatome glue Since this dermatome is dependent upon the adhesiveness between the skin and the drum great care must be taken in preparing a donor site If powder from the surgeon's glove falls on the donor site or if a small amount of blood, water or skin oil remains on the region, the glue will not stick in that area and a full drum of skin cannot be obtained Glue that has remained in a container for a long time may be too thick It may be thinned by adding a small amount of ether It is best to pour the glue from its sealed container just before it is used When glue is allowed to stand open on the table it may become quite thick, hence it cannot be spread evenly on the dermatome

The drum is prepared by first cleansing it with ether to remove any oil and then by applying a thin layer of glue over the entire drum The glue must be spread evenly and completely on the edges of the drum This is accomplished by using a small brush or, better still, a piece of gauze folded and grasped with sponge forceps It is a common mistake to apply too little glue rather than too much Care must be taken to place an adequate amount of glue on the leading edge of the dermatome because it is particularly important to have proper adhesiveness in this area If the drum does not stick at the leading edge when the graft is started it is very difficult to obtain a good drum of skin

The glue on the drum and the skin is permitted to dry or set for several minutes Three minutes is usually adequate but the glue sticks better after an interval of five minutes. If ether has been used to thin the glue, an even longer delay is indicated A small amount of Vaseline placed on the back of the blade holder causes it to slip over the skin smoothly

The depth of the cut is determined by a lever on the side of the handle The distance between the blade and the surface of the drum may be altered by rotating this lever and thus varying the depth of the cut It is always advisable to look at the alignment between the blade and the surface of the drum before starting to cut the graft Occasion ally the drum is warped or the blade is out of alignment and, unless the instrument is checked before use an uneven cut may be obtained

In order to have a good initial sealing between skin and drum, pressure must be used in applying the leading edge of the drum to the donor site As soon as a satisfactory seal is made, the cut is started The area from which the skin is to be removed is measured carefully by eye before the drum is applied The drum is placed on the skin in



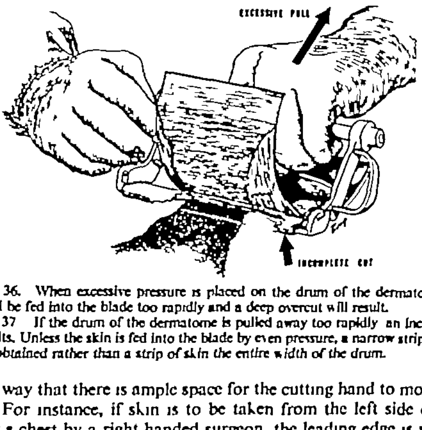


FIG. 36. When excessive pressure is placed on the drum of the dermatome, the skin will be fed into the blade too rapidly and a deep overcut will result.

FIG. 37. If the drum of the dermatome is pulled away too rapidly an incomplete cut results. Unless the skin is fed into the blade by even pressure, a narrow strip of skin will be obtained rather than a strip of skin the entire width of the drum.

such a way that there is ample space for the cutting hand to move the blade For instance, if skin is to be taken from the left side of the patient's chest by a right handed surgeon the leading edge is placed on the lower part of the chest and the cut starts at the bottom, moving upward toward the axilla in order to permit freedom of the cutting hand.

The hand holding the dermatome must remain steady at all times Because the hand that operates the blade is moving back and forth constantly it is not uncommon for the opposite hand which controls the drum to be in rhythm with the hand on the blade As a result, the

drum moves back and forth over the donor surface This can be corrected only by practice It is important for the drum to move along a straight line over the skin rather than to twist it at an angle The blade cuts the skin much more smoothly if it is worked back and forth in a sawing motion while the drum is being advanced slowly The drum should not be rotated too rapidly Constant pressure should be exerted on the drum in an upward and forward direction in order to feed the skin into the blade If an excessive pressure is exerted, however, a wider piece of skin will be fed into the blade, resulting in deep overcuts (Fig. 36) On the other hand, if the drum is pulled away too fast, the full width desired will not be obtained (Fig. 37)

The operator must focus his attention at all times on the point at which he is cutting to make sure that the blade does not overcut and that a full drum of skin is removed It is advantageous for the operator to watch the right side of the drum and let his assistant observe the left side If a full drum of skin is not being removed, then a little more pressure must be exerted with the drum hand and the cutting stoke must be shortened If there is a tendency to overcut, the drum is pulled away a little more rapidly and the stroke is lengthened slightly

There are several methods of removing the skin from the dermatome The most common method is simply to cut the skin free with a sharp knife, place the dermatome in its rack, and peel the skin away by means of several hemostats The disadvantage in using this method is that the glue on the back of the skin is still present and causes the skin to wrinkle and stick together This makes it difficult to handle

A better method for removing skin from the dermatome is to loosen the skin while it is still attached to the donor site Upon reaching the end of the graft, slight tension may be exerted on the drum in order to pull the skin away from the drum as far as the leading edge (Fig. 38) The glued surface and the base of the skin are then covered with blood from the donor site This procedure eliminates the stickiness and also avoids tearing as the skin is being removed from the drum The skin remains suspended between the donor site and the leading edge of the dermatome therefore it can easily be cut free from the donor site with a pair of scissors or a knife Care must be taken when a knife is used or it may cut into the subcutaneous tissue

After the skin is removed from the drum the dermatome is placed on its stand The drum is then cleaned and reglued in order to be ready to take the next sheet of skin The simplest method of cleaning a dermatome is to rub the drum surface vigorously with a dry sponge Since the glue is a plastic like material, it will roll up and separate readily from the instrument The drum should be further cleansed with ether before a new application of glue is made

FIG 38 Method for removing skin from the dermatome drum and the base of the skin are covered with blood from the donor site. stickiness and avoids tearing the skin as it is removed from the dr

FIG. 39 The number of sheets of skin that can be removed fro pends upon the size of the patient. Outlines in the diagrams above pr amount of skin without interfering with critical areas. The area superior iliac spine should be avoided The area near the anterior axil be used because motion of the arms prevents optimum healing in that take skin transversely over the lower chest and center of the back th It is difficult to remove a strip of skin in a longitudinal direction fro chest by means of the drum-type dermatome.

Several sheets of skin may be removed from the fro the trunk if the donor areas are properly placed (Fig 3

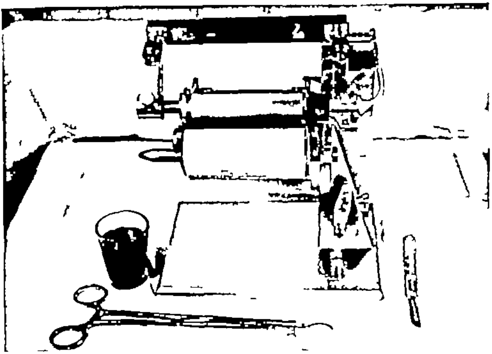


FIG. 40 The Reese dermatome on its stand. The dermatape has been placed on the dermatome but the white linen backing has not been removed. The medicine glass holds liquid cement to be painted on the skin. Gauze is folded and grasped with sponge forceps to be used for painting the skin.

However the Reese dermatome is a much heavier instrument and it is built more solidly This is advantageous in that it helps the surgeon to hold the instrument steady while he is cutting the skin

The method of regulating the depth of cut has been modified on the Reese dermatome. A series of shims are supplied with the instrument and they are fitted between the blade and blade holder in order to regulate the thickness of the skin to be cut This modification is advantageous because it produces an absolutely uniform thickness of skin which does not change during the process of cutting For a beginner, the Reese dermatome is nearly foolproof and as a result, a full drum of skin can usually be taken by an inexperienced operator However, the Reese instrument is heavier and more cumbersome than the Padgett dermatome and therefore cannot be used with the same agility

The one outstanding advantage of the Reese dermatome is the addition of dermatape as a backing for the skin A green, rubberized material fits over the back of the drum This material is attached at one end and then it is placed over the drum and tightened by means of a worm gear spool at the other end Once the dermatape is applied tightly, similar in a manner to that of a roll of film the dermatome is ready for use. Dermatome cement is painted on the skin The green dermatape is covered with a white glazed linen backing which is

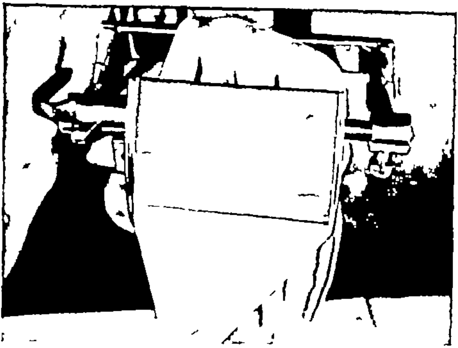


FIG. 41 Immediately prior to placing the dermatome on the skin, the linen backing is removed from the dermatape. This linen backing protects the adhesiveness of the dermatape.

peeled off before the dermatome is used (Fig 41) The adhesive layer of the green rubber backing is thereby protected from becoming soiled before being used The dermatapes are sterilized by soaking in cold sterilization solutions, such as Zephiran

This instrument can be used more rapidly than the Padgett derma tome because the drum does not have to be cleansed between grafting procedures The surgeon simply removes the dermatape backing with the skin attached and then places another dermatape on the drum. The skin may be left glued to the dermatape and later the dermatape may be cut to fit any particular pattern desired This is advantageous when postage stamp type grafts are to be applied The dermatape keeps the skin adherent to the backing and prevents it from curling and shrinking. The dermatape may be removed from the grafts at the first dressing change It is expensive to use a Reese dermatome be cause dermatapes are required for each cut of skin

Other Types of Dermatomes

Several modifications of the electric dermatome have been made by European surgeons. One of interest is a dermatome that is run by compressed air somewhat similar in construction to the electric dermatome The blade of this particular instrument does not run as rapidly as the blade of an electric dermatome and therefore it is more difficult to obtain a clean cut

FIG. 42

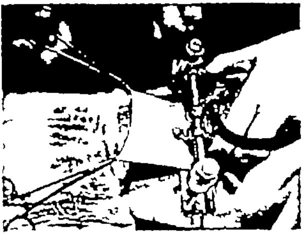


FIG 43

FIG. 42. Stryker electric dermatome. The skin graft is cut by means of a circular blade that oscillates the same as the blade on the Stryker bone saw The maximum width of the strip of skin taken by this instrument is two inches.

FIG. 43 The Barker Vacutome. A replaceable knife with a long replaceable blade is used behind a vacuum cup The length of skin to be cut by this instrument is limited only by the extent of the donor site.

STRYKER ELECTRIC DERMATOME. This is an instrument which has been designed to fit the Stryker electric bone saw thus it has a dual purpose (Fig. 42) The grafts are cut by means of a circular blade that oscillates the same as the blade on the Stryker saw The depth of the cut is set before the blade is locked into position by means of shims fitted between the guide bar and the blade This instrument is more difficult to use then a Brown electric dermatome, and it can cut a strip of skin only 2 inches wide. This instrument has relatively little value for skin grafting of burns, however it is of great value to the orthopedic surgeons who do extensive bone work since it is an integral part of the commonly used bone saw

BARKER VACUTOME. This instrument utilizes the principle of a suction cup with a knife attached for cutting skin (Fig. 43) A standard, long blade, replaceable knife is used behind a vacuum cup After preparing the skin a thin layer of mineral oil is applied over the blade and the donor site The suction box is then pressed against the skin where it is held until the suction gauge registers approximately 15 The blade is placed in the cutting position in somewhat the same manner as that used in the Padgett or Reese dermatomes. The length of skin to be cut is limited only by the extent of the donor site. Since this instrument works on a suction principle, it is necessary to have

an absolutely flat smooth surface in order to maintain suctio sheets of skin may be obtained with this instrument How does not afford any advantage over an electric dermatome

Freehand Knife

The earliest method of obtaining split thickness skin gra by means of the freehand knife A straight-edged razor may but the width of the graft will be limited A double-edged razo grasped between the jaws of a straight hemostat may be used to small pieces of skin However the preferred instrument for fr cutting is the Blair Brown knife or the Ferris Smith knife The on either of these instruments are approximately five to six in length The blades are removable and whenever necessary blade may be inserted

There are several advantages in using the freehand knife Th is inexpensive and is almost universally available. The length graft that is taken is limited only by the skill of the surgeon a location of the donor site However, there are two disadvant the use of the freehand knife (1) in order to use the knife p a great amount of skill is required and (2) regardless of the cutting the skin with a freehand knife it is almost impossible move a sheet with uniform depth throughout the entire width o Unless a surgeon is particularly adept in the use of the freehand he will frequently make deep cuts in the donor site

A device known as the Mark attachment has been dev which fits the Blair Brown knife and simplifies the taking o thickness grafts (Fig 44) This attachment consists of a small n roller bar approximately ¼ inch in diameter attached to the just in front of the blade The depth of the cut is set by adjust distance between the blade and the roller bar through a set of supplied with the knife The use of this attachment enables the s to cut a graft of uniform depth A similar type of instrument is in England and is known as the Humby knife

It is advantageous to apply a small amount of mineral oil back of the knife to make it slide easily over the surface Bef attempt is made to cut the skin it should be stretched tight with a suction cup or by means of two skin boards. The assista control counter tension by means of the two skin boards The g cut with long, even strokes of the knife and the surgeon must about 1 or 2 inches behind the lead board As the skin is cut the end may be held by an assistant in such a manner that the surg able to observe the thickness of the graft

Because of the considerable amount of practice required in th

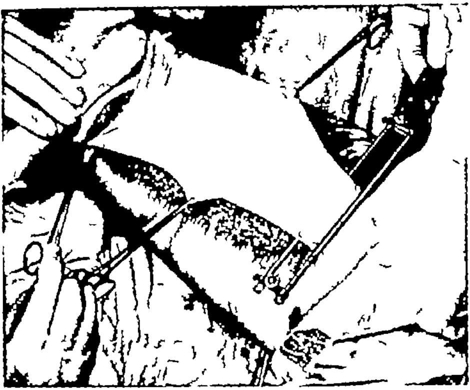


FIG 44 Cutting skin with a freehand Blair Brown knife. Considerable practice is required in order to take large sheets of split thickness skin by this method.

of a freehand knife and the availability of various types of other skin cutting instruments, the knife is rarely used unless it is necessary to cut small pieces of skin for application as postage stamp grafts If only one small piece of skin is required a razor blade or a freehand knife may be used to cut the skin in order to save the surgeon's time in setting up an electric dermatome. The freehand knife is of value in slicing off heaped up granulations from a burned surface months after injury

TREATMENT OF DONOR SITES

For many years the accepted method of management of donor sites has been the application of an occlusive dressing after hemostasis Various preparations have been suggested for local application These include petrolatum gauze Xeroform gauze nylon spun glass, metal foils as well as scarlet red boric acid furacin and other chemotherapeutic ointments In most instances the occlusive dressing method yields good results As long as a wound is kept free from infection the remaining epithelial islets regenerate and healing occurs Epithelization is delayed by motion beneath the dressing Mechanical trauma and infection are usually the chief deterrents to proper healing. Infection is the most common complication Within the last decade the exposure method has been used rather widely and exceptionally good results have been obtained particularly in warm climates -

If the wound is to be treated by dressings the surgeon ap large bulky, occlusive dressing. The dressing is put on in such that it completely occludes the wound thereby preventing b invasion A dressing must be thick enough to be absorptive an enough to afford a certain amount of splinting to the wound I be wrapped with some type of elastic bandage in order to appl resilient compression to the area

Dressings are allowed to remain in place for approximat days However, they must be examined frequently and re earlier if there is any evidence of infection After 14 days the d may be gently removed as far as the layer of fine mesh gauze gauze seems to stick to the underlying surface it must not be re because it will tear away a thin layer of epithelium The fine gauze is allowed to remain in place until it falls off In most inst very good results are obtained by this method Dressings are and sometimes very uncomfortable. They are unusually warm ally if the patient is hospitalized in a warm humid climate If tient has only one donor site a dressing may be applied W patient has sustained an extensive burn and he has bulky dre covering the large grafted surfaces additional dressings on the site tend to increase discomfort In extensive burns where the sites must be interspersed between infected granulating are fection of the donor site occurs because it is difficult to isola donor area with an adequate occlusive dressing

In most burned patients, treatment of donor sites by the exp method is superior to the occlusive dressing method (Fig 45 mediately after the skin graft has been removed the donor a covered with dry fine mesh gauze (gauze roller bandage) A moist thick gauze pad is then applied to achieve hemostasis. end of the operation the gauze pad is removed The blood sc fine-mesh gauze is allowed to remain as the only covering wound All free edges of fine mesh gauze are trimmed away

The area of the donor site is permitted to remain exposed air A firm coagulum soon forms from the blood that is caught interlacing fibers of the gauze This coagulum dries within 24 and when hardened serves as a protective covering for the w The patient usually complains of moderate pain until the coag dries but this discomfort may be relieved by minimal doses narcotic After the coagulum hardens the patient has no furthe comfort from the donor area Epithelization proceeds beneat coagulum As healing progresses the protective covering loose the edges and must be trimmed When healing is complete the c *ing falls off leaving a well epithelized surface.*

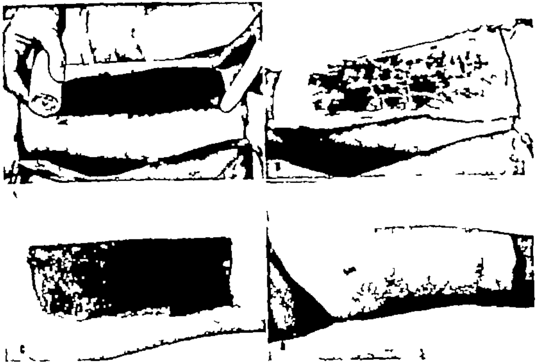


FIG. 45 *A* After the graft has been removed, a layer of fine-mesh gauze is placed over the donor area.

B A warm, moist, laparotomy pad is placed over the donor site for hemostasis. This is removed at the end of the operative procedure.

C Blood has coagulated in the interstices of the fine-mesh gauze. This forms a hard coagulum that serves as a protective cover for the wound

D The 12th postoperative day Epithelial growth has occurred beneath the fine-mesh gauze coagulum.

Although a temporary dressing over the fine mesh gauze on the donor site may alleviate pain for the first 24 or 48 hours its use is not warranted because of the pain and renewed bleeding associated with its subsequent removal. The disadvantage in using the exposure method in the treatment of donor sites is that they must be planned in such a way as to permit their being exposed Selection of various areas for donor sites usually can be planned to permit one side of the body to be used for one grafting procedure and the other side to be used at a later time. Exposed donor sites are more comfortable, less frequently complicated by infection, and easily observable

Infected Donor Sites

Infection interferes with healing and occasionally it may actually destroy the remaining viable epithelium, thereby converting the donor site to full thickness injury If infection occurs beneath a dressing, the dressing must be removed down to the fine mesh gauze the area is then treated by the exposure method It may even be necessary to apply an appropriate antibiotic locally or to treat the area with wet dressings

An occasional donor site which has been treated by exposure may become infected Infection can be detected as soon as it starts because exposure permits constant visualization of a donor site When infection occurs it is wise to cut away the fine mesh gauze coagulum and apply wet dressings *Infected donor sites can usually be prevented by selecting the proper donor area* If skin is removed from areas of motion or from an area adjacent to the perineum the donor site often becomes infected

When a donor site becomes infected and converted to full thickness injury as evidenced by the formation of granulation tissue it must not be treated as a donor site but as a granulating wound When this occurs the surface should be properly prepared and a thin, split thickness skin graft applied

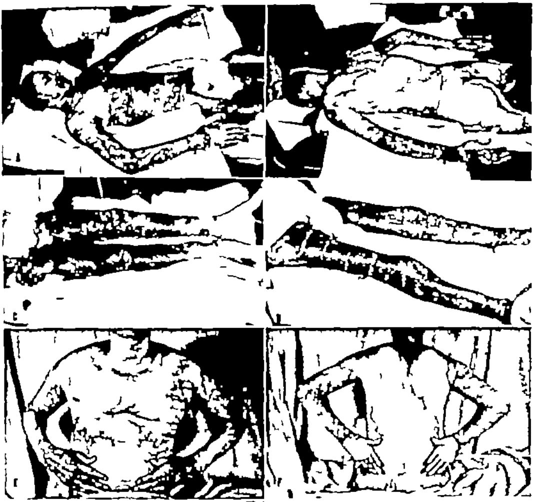
HOMOGRAFTS AS A TEMPORARY COVER FOR THE WOUND

For permanent wound closure third-degree burns must be grafted *with autogenous skin* An extensively burned patient however may not have sufficient donor sites for this purpose Such severely burned patients may not be able to tolerate the additional trauma associated with skin removal and homografts may be lifesaving [4] Although *homografts provide only a temporary cover for the wound their use* makes possible a period of time during which the patient s condition may be improved both from a nutritional standpoint and from the standpoint of local care of the wound (Fig 46) Homografts also furnish a temporary coverage for some of the granulating areas while donor sites heal sufficiently to be used again Homografts may be applied on the granulating areas without using general anesthesia After they are applied a patient sustains less infection less fibrosis and less discomfort Usually, the patient s morale is improved and his nutritional intake is increased

Homografts survive for one to seven weeks, their mean survival time being four weeks [3] As soon as a homograft sloughs the area is prepared for grafting with autogenous skin Jackson has pointed out that in some instances a strip of autogenous skin approximately ½ inch in width may be alternated with strips of homografts cut to a similar width As the homograft disappears epithelium from the autogenous areas usually grows in from the edges and covers the surface [6, 7]

The chief indications for the use of homografts are

1 In an extensively burned patient when autografts are available for only a portion of the wound the remainder may be covered with homografts This is not necessary in all patients. If it is believed that



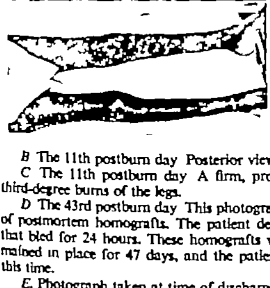


FIG 46. *A* This soldier sustained a total body surface burn of 72 per cent, 43 per cent being third degree, when a howitzer shell accidentally exploded in the chamber This photograph was taken 11 days after injury The patient was placed on a Stryker frame and the entire burn wound was exposed.

B The 11th postburn day Posterior view

C The 11th postburn day A firm, protective eschar has formed over the deep third-degree burns of the legs.

D The 43rd postburn day This photograph was taken 11 days after the application of postmortem homografts. The patient developed septicemia and a Curling's ulcer that bled for 24 hours. These homografts were applied without anesthesia They remained in place for 47 days, and the patient's condition improved markedly during this time.

E Photograph taken at time of discharge.

F At time of discharge, the deep dermal burns of the back have healed. The arms were covered with postage-stamp grafts.

G As the homografts on the legs disappeared, the areas were covered with postage-stamp autografts. The dorsum of the feet was used as donor sites on two occasions.

the wound is so extensive that leaving part of it open might furnish too large an avenue for invasive infection the application of a homograft is indicated

2. Homografts are used on a moderate burn wound that may have developed some complication, such as septicemia, especially if the added insult of anesthesia is inadvisable In such instances, homografts are placed on the granulating surface without using anesthesia (Fig 46 D)

3 Application of homografts is desirable for patients who have open granulating areas of considerable extent and who have become seriously debilitated During the time the homografts remain in place a better nutritional state may be obtained in order that the patient may withstand the further trauma of anesthesia and grafting. As has been pointed out repeatedly by Brown homografts are used as a temporary skin dressing [4]

Whenever possible fresh rather than stored homografts should be used They may be taken either from a live donor or from a cadaver Fresh, postmortem homografts seem to take as well as homografts procured from living donors. Homografts from a member of the family or from an individual with a similar blood type do not persist any longer than homografts obtained from any available donor

If a large amount of skin is required it is advisable to take homografts from several donors Three long strips of skin may be cut from the anterior aspect of each thigh and this is the maximum amount that should be removed from a single donor There are many obvious advantages to postmortem homografts [3] Permission must be obtained from the relatives to remove several strips of split thickness skin from the body of the deceased person The skin of patients dying of cancer tuberculosis syphilis, septicemia homologous serum hepatitis and communicable diseases or diseases having cutaneous manifestations is not suitable as a homograft The body of the deceased person is brought into the operating room as soon as possible after death preferably within four hours Areas selected for removal of skin are treated with the usual preoperative preparation of the skin The areas are draped then sheets of skin from 012 to 015 inch in thickness are removed expeditiously by means of an electric dermatome The areas most easily accessible are the lower extremities and back

After the skin is removed it is placed on petrolatum impregnated fine mesh gauze in such a manner that the cut surface is away from the gauze This skin and gauze are then folded to bring the cut surfaces of the skin in apposition The skin is placed in a covered receptacle containing 20 to 30 cc of isotonic saline 300 000 units of penicillin and 0 5 gram of streptomycin The skin is stored in the nonfreezing com

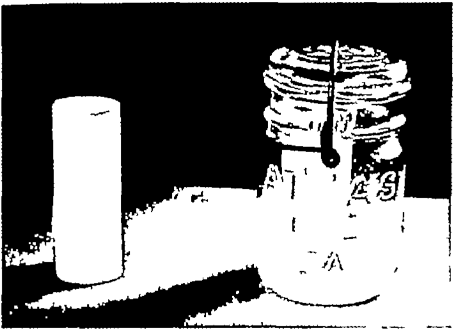


FIG 47 Method of preparing lightly-impregnated petrolatum gauze. A three-inch gauze roller bandage is placed in a jar and white petrolatum is added before autoclaving An excessive amount of petrolatum does not adhere to the fine-mesh gauze. The roll is easy to handle.

partment of a refrigerator until it is applied An alternate method is to make sure that the skin is dry fold it on dry gauze and put it in a deep freeze Successful takes of grafts may be expected in skin that has been stored for five to seven days It is advisable, however to apply the skin as soon as possible after it has been removed

Although homografts may take after prolonged storage they seem to remain in place longer if they are applied within a few hours after they are obtained from the donor Various methods for storage of skin are being investigated Several methods seem to be satisfactory but those suggested in the preceding paragraph seem to be the most practical

APPLICATION OF SKIN TO THE WOUND

As soon as skin has been removed it is placed in a pan of saline solution to keep it moist. A nurse can then place the strips of skin on petrolatum-impregnated gauze to make handling easier

The simplest way to impregnate fine-mesh gauze with petrolatum is to place a three-inch roller bandage in a pint jar and add white petrolatum until the jar is about one third full cover the jar and autoclave The pressure and heat of the autoclave causes the petrolatum to penetrate the meshes of the roller bandage (Fig. 47) The roll is easy to handle and an excessive amount of petrolatum does not adhere to the fine mesh gauze

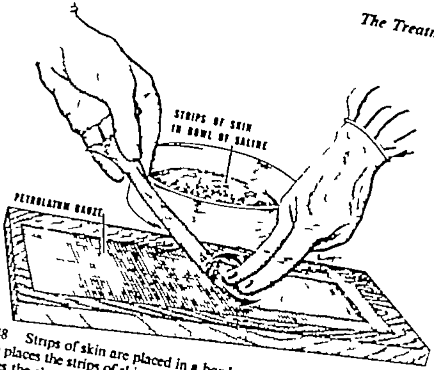


Fig 48 Strips of skin are placed in a bowl of saline as soon as they are removed. The nurse places the strips of skin with the epithelial side next to the petrolatum gauze. This makes the sheets of skin easy to handle.

This impregnated gauze is placed on a skin board and each strip of skin is placed with the external surface next to the gauze The excess gauze is then trimmed away Strips of skin usually curl but if they are kept moist in saline and pressed firmly against the petrolatum impregnated gauze they remain flat and their edges do not curl (Fig 48) Each strip of skin placed on petrolatum-impregnated gauze may be folded over and placed between moist gauze pads until the surgeon is ready to apply the skin

The application of skin grafts in burn therapy may be carried out by three different methods lay-on method suture method and postage-stamp method

Lay-on Method

This is the best method for applying split thickness grafts to large flat surfaces It is both rapid and effective A sheet of skin is placed over the recipient area then the petrolatum impregnated gauze is removed The skin is arranged in such a way that the sheets are placed in close apposition (Fig 29 D) Grafts are held in place by applying a firm dressing. This method of applying skin is quite effective for flat surfaces providing a dressing can be applied to hold it firmly in place It cannot be used on irregular surfaces however as the skin is likely to become wrinkled or to slip

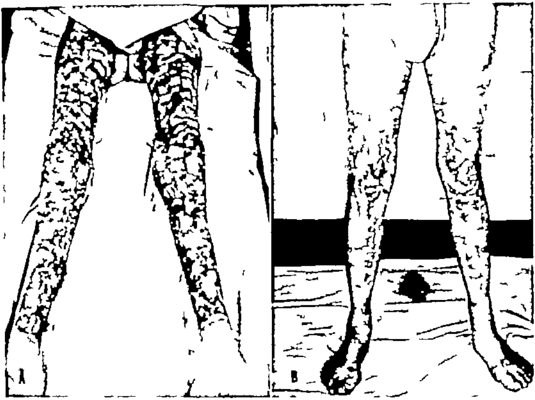


FIG 49 *A* This patient had a very extensive burn and only a limited amount of skin was available. Postage-stamp grafts have been applied to the lower legs.
B The legs have healed and the postage-stamp grafts have provided good cover

Suture Method

Grafts should be sutured in place over irregular surfaces and points of motion, such as on the chin neck, feet, or hands, or around the knee and the elbow Very fine 0000 silk sutures may be used on a sharp cutting needle Deep bites into the underlying tissue must be taken in order to prevent excessive bleeding. Little time is required to suture grafts in place if the areas to be grafted are small When extensive areas are to be grafted, however suturing of all the sheets of the skin prolongs the operative procedure unduly

Postage-Stamp Method

Postage stamp grafts are cut about 1 by 2 inches in size and placed in bricklayer fashion not further than ½ inch apart (Fig 49) The grafts and the gauze backing may be cut together allowing the backing to remain in place until the first dressing change Postage stamp grafts are easily applied when the skin has been taken with a Reese dermatome Suturing is unnecessary since the grafts are held in place by the dressing because of the dermatome backing (Fig 50)

This method should be used when the recipient site is so extensive that only quite limited amounts of skin are available for grafting

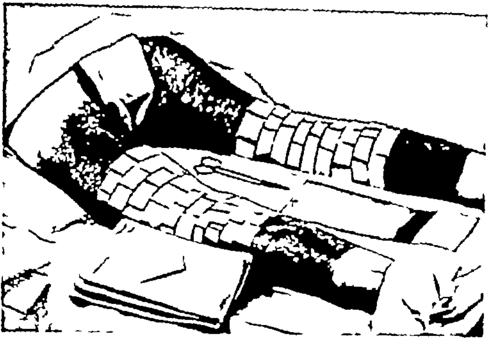


FIG. 50. Skin has been taken with the Reese dermatome. Postage-stamp grafts have been cut from the skin on the Reese dermatape. Such grafts are very easily applied.

Postage-stamp grafts must not be used to cover points of motion as they may cause increased scarring. They can provide adequate cover on large flat surfaces. If large surfaces are to be grafted and the recipient site is not in good condition, postage-stamp grafts permit drainage between the grafts, hence the take is better than if large sheets are applied. If there is a good recipient site, sheet grafts by the lay-on method result in less scarring and are therefore preferable. Postage-stamp grafts are also used to cover small areas that remain open after grafting with sheets of skin.

Sometimes a small amount of skin is left over after grafts have been applied. This skin with its petrolatum-gauze backing can be placed in a large Petri dish or some other suitable covered container and stored in a refrigerator. The skin should not be stored in the freezing compartment. After the first dressing change, this excess skin may be used for patching some areas where grafts have not taken.

Perforation of Grafts

Small perforations must be made in grafts occasionally because of the fear that serum might collect beneath a graft and prevent a good take. If postage stamp grafts are applied, perforations are not necessary. When large sheets of skin are sutured in place, it is advisable to make small perforations in the graft at any point where a collection of serum might be apt to form. Routine perforation of grafts, how

ever, is unnecessary When large sheets of skin are placed over a flat surface, a perforation serves no useful purpose and is of doubtful value. It usually leads to delayed healing and unnecessary scarring. On the other hand if the surface is uneven and a dependent area might be a focal point for a collection of serum the graft should be perforated at that point

APPLICATION OF THE DRESSING OVER A GRAFT

One of the most important factors in grafting is the application of a good dressing. This procedure must be carried out with great care Most grafts are held in place by a dressing, hence the dressing must be firm, bulky, and capable of producing even compression As soon as the grafts are applied, irrespective of the method of application a layer of gauze is lightly impregnated with petrolatum and placed over the grafts to hold them in place A large number of fluffs to make a bulky dressing are then added after which an elastic bandage is wrapped around the dressing to provide even, firm compression A dressing similar to that used in second-degree burns is ideal (see Fig. 19, p 60)

Although the grafting procedure is almost complete at the time a bandage is to be applied the anesthesiologist must be cautioned that this is the most important time to keep the patient asleep and free from motion All too frequently, an anesthesiologist thinks that the patient should be awakening as the operative procedure draws to a close and, as a result, the patient will move at the time when the dressing is being applied Motion disturbs the position of the grafts and prevents a good take.

The dressing should be large enough to serve as a splint If it does not completely immobilize the area, a plaster splint should be applied Motion is one of the important factors in the failure of a graft to take

A poor dressing is often applied because the surgeon is fatigued after a three- or four hour operation If extensive burns are being grafted, it is usually advisable for one member of the team to withdraw for a few minutes of rest prior to the conclusion of the operation After the grafts are in place, he may rescrub and apply a good dressing.

Every dressing should be labeled by date of grafting and type of dressing applied If a leg has been grafted, it is advisable to include the foot in the dressing in order to keep it in a position of function and to exert an even compression over the entire leg and the foot By placing the dressing over the joints both above and below the graft better immobilization is obtained

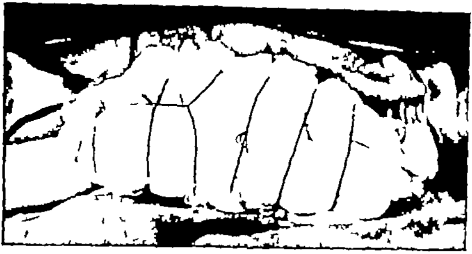


FIG. 51 On-lay gauze dressing, or stent dressing. Heavy black silk sutures are placed in the normal skin surrounding the grafts. These are then tied over the large bulky gauze dressing. Such a dressing holds the grafts firmly in place and serves as a splint to the area. Stent dressings are particularly indicated over rough, irregular surfaces.

On-Lay Gauze Dressings

On lay gauze dressings commonly known as stented dressings are extremely valuable for holding grafts in place over irregular surfaces They are particularly valuable over grafts on the head on the neck around the shoulder, or on the buttocks Heavy silk sutures *are placed in the normal tissue surrounding the area and tied over* fluffed gauze (Fig 51) This not only immobilizes the graft but it also maintains even compression on the graft Stented dressings are used *whenever it is felt that firm compression cannot be maintained by the* usual type of dressing

AFTERCARE OF GRAFTS

There are three important factors that hinder the take of a skin graft infection motion and poor condition of the recipient site Infection caused by group A beta hemolytic streptococci may produce sloughing of the grafts and a poor take The take of a graft is not materially affected by other species of bacteria unless the bacterial population on the wound is very large Almost any area may become infected with *Pseudomonas* but this microorganism disappears upon application of the graft (see Chapter 7)

Motion is a very common cause of failure of graft take Inadequate fixation or undue voluntary movement of the grafted area may displace grafts in the early postoperative period For this reason the grafted part needs to be observed carefully during the postoperative period in order to make sure *that the patient does not move the area*

excessively In extensive grafting procedures, it is sometimes necessary to sedate the patient for 24 hours in order to insure immobilization

A poor recipient site affects the take of a graft adversely Granulations having a fibrous base prevent grafts from obtaining a good blood supply and a poor take results

Dressings should be changed between the third and the sixth day If the surface on which the graft is placed is in poor condition the graft should be inspected on the third day If the recipient site appears to be free from infection, then it is safe to allow the dressing to remain in place for five or six days At the first dressing change great care must be exercised to prevent pulling away grafts that are not firmly fixed When graft and gauze are adherent irrigation by means of a bulb syringe tends to loosen the gauze and thus prevents grafts from being torn from their base It is not always necessary to perform graft changes under anesthesia Anesthesia should be avoided at a dressing change whenever possible but, if a dressing procedure is very extensive anesthesia is necessary to prevent undue pain and motion

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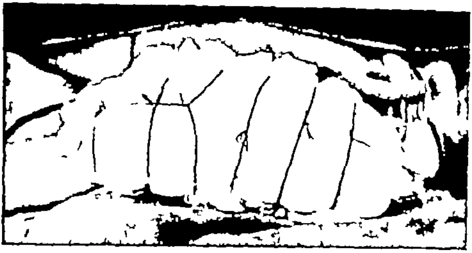
The Hubbard tank is an excellent method for stimulating motion and keeping the grafted areas clean (Fig 52) As soon as the dressings have been removed on an extensively burned patient it is advantageous if he be placed in a Hubbard tank at least once a day When muscular tone returns to the lower extremities, the patient may become ambulatory Early motion and early ambulation are desirable The Hubbard tank has one disadvantage and that is possible cross-contamination of open areas.



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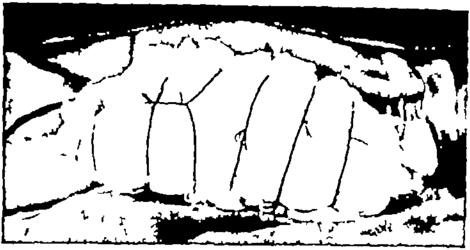

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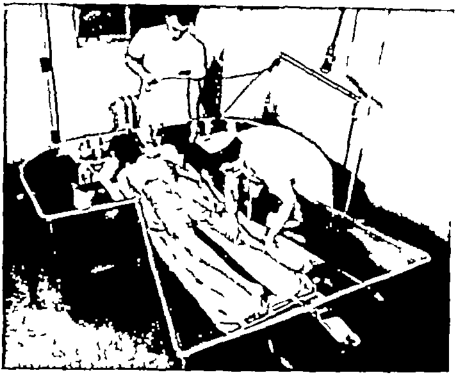

FIG. 52. Patient in a Hubbard tank. As soon as grafts have taken, a patient may be placed in a Hubbard tank. This stimulates motion and keeps the grafted areas clean.

When a patient with burns of the lower legs becomes ambulatory he should wear an elastic rubberized bandage. Such a bandage or elastic stocking is worn over grafts on the lower extremities for a period of three to six months. This support for freshly grafted areas and donor sites is necessary in order to prevent breakdown of the epithelium and subsequent small ulcerations.

Occupational therapy is desirable. It stimulates the patient's desire to rehabilitate himself and also improves his morale. As soon as the granulating wounds are covered, a complete change occurs in the general condition of the patient. He suffers less pain, he feels much better, his appetite improves and he begins to gain weight. A patient may lose as much as one pound per day during the early period following a burn but he is able to gain from one-half to one pound a day after the wounds have been closed by grafting.

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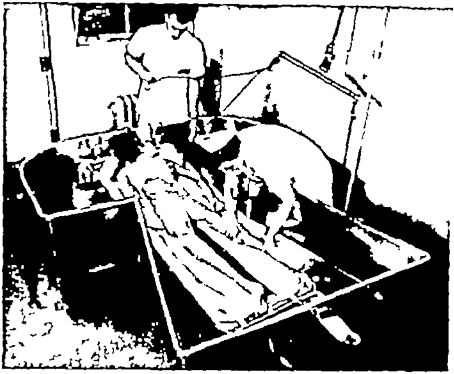

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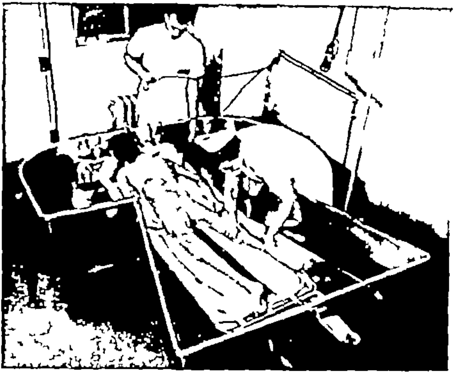

FIG 52. Patient in a Hubbard tank. As soon as grafts have taken, a patient may be placed in a Hubbard tank. This stimulates motion and keeps the grafted areas clean.

When a patient with burns of the lower legs becomes ambulatory he should wear an elastic, rubberized bandage Such a bandage or elastic stocking is worn over grafts on the lower extremities for a period of three to six months This support for freshly grafted areas and donor sites is necessary in order to prevent breakdown of the epithelium and subsequent small ulcerations

Occupational therapy is desirable It stimulates the patient's desire to rehabilitate himself and also improves his morale As soon as the granulating wounds are covered a complete change occurs in the general condition of the patient. He suffers less pain he feels much better his appetite improves and he begins to gain weight A patient may lose as much as one pound per day during the early period following a burn but he is able to gain from one half to one pound a day after the wounds have been closed by grafting.

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CHAPTER 6

Burns of Specific Areas

BURNS IN CERTAIN regions of the body present some special difficulties. Recommendations for therapy of these specific areas may be helpful

BURNS ABOUT THE HEAD

Management is particularly difficult of burns about the head because of the many important functional organs involved For some unexplained reason a more marked systemic response appears to be associated with deep burns about the face and neck than with burns of comparable extent in other areas Extensive edema occurs because the loose areolar tissues around the face and neck offer little tissue pressure to oppose extravasation of edema fluid If a burn of the head is of appreciable extent disorientation is common Patients are more concerned about burns of the head because of the fear of disfigurement

Burns of the Face

Rapidly developing edema is characteristic of burns of the face The eyelids become edematous and are usually closed tightly within six to eight hours after injury Most of the edema occurs in the first *24 hours although it does not reach its maximum formation until* about 48 hours (see Fig 8 p 28) It is difficult to determine accurately the depth of a burn on the face Occasionally the injury appears to be third degree initially but with proper care epithelization occurs in many areas from the lining of the hair follicles

The principal initial problem in burns about the face and neck is to determine the presence of respiratory tract irritation When such involvement is seen an early tracheotomy is indicated (see Respiratory Tract Damage p 127)

Initial cleansing and removal of all detached epithelium are indicated If the burn involves the *hair* or is near the *hairline* the *hair*

FIG. 53 The hair should be clipped during initial cleansing of the face, especially if the burn involves the hairline. This patient had a partial and full-thickness burn of the face that was cleansed gently with soap and water An elective tracheotomy was performed 12 hours after the burn before appreciable edema had occurred in the neck.

should be removed by clippers when the initial cleansing is performed (Fig 53) Both second-degree and third-degree burns of the face do well when treated by the exposure method Dressings are extremely uncomfortable and it is difficult to apply them properly Both the patient and his family should be informed of the likely formation of edema. They should be forewarned about the closure of the eyelids for the first 48 to 72 hours.

Superficial second-degree burns usually heal uneventfully without scarring in 14 to 21 days (Fig 54) In deep dermal burns, the crust may crack as the beard grows. When this occurs, wet dressings should be applied to hasten the removal of the crust and to prevent infection from destroying the underlying epithelium (Fig. 55)

When full-thickness burns are exposed, the pearly white dead skin dries and serves as a temporary protective cover About the end of the first week when bacterial autolysis begins wet saline dressings applied every four hours soften the eschar and hasten its sequestration and subsequent removal Grafting can usually be performed by the 18th to 21st day (Fig 56) Excision of eschars of the face is indicated only in rare instances (see Chapter 9)

FIG 54 *A* Deep partial-thickness burn of the face two days after injury The area was cleansed with soap and water All devitalized epithelium was removed, and hair adjacent to the burn was clipped. The face was treated by the exposure method.

B A month later the face is completely healed with little evidence of scarring The tracheotomy remains in place for administration of anesthesia for another operative procedure on the legs.

FIG 55 Typical wet dressings applied to a third-degree burn of the face. A tracheotomy is in place. The plastic nasogastric tube is used for feeding purposes. Saline dressings are changed every four hours to expedite removal of eschar

Burns of the face and the hands should be given first priority for skin cover Thick split thickness sheets of skin must be applied Additional plastic procedures for cosmetic and functional purposes are usually not indicated for at least six months Occasionally, if there is significant functional impairment, it may be necessary to reconstruct eyelids or relieve contractures about the mouth prior to six months

Burns of the Eyelids

Burns of the eyelids occur frequently when the face is burned. However burns of the sclera and cornea are rare Usually the eyelids close by reflex action and the cornea and sclera are not damaged Occasionally a flash burn affects these areas, but the mild irritation produced usually heals within two days

In partial thickness burns of the eyelids, edema closes the eyes for a period of 48 to 72 hours The important therapy during this period is routine eye care such as irrigation with saline and the in

FIG 56 *A* Third-degree burn of the face at 24 hours following injury Edema of the eyelids has resulted in their closure. The tracheotomy makes it possible to maintain a clean trachea The burn was treated by the exposure method.

B The 26th postburn day Wet dressings were applied to the face beginning on the 8th postburn day The entire eschar has been removed and the area is ready for the application of a graft.

C The 30th postburn day At the initial grafting procedure a tarsorrhaphy was performed on each eye Almost all of the face was covered by split thickness grafts. The plastic nasogastric tube was used for feeding purposes. Anesthesia is being administered through an endotracheal tube placed in the tracheotomy opening

D Seven months after injury The tarsorrhaphy on the left eye has been opened and a small skin graft has been placed beneath the lower lid. The right tarsorrhaphy is still intact Considerable loss of cartilage resulted from deep burns of both ears. A contracture about the mouth required correction.

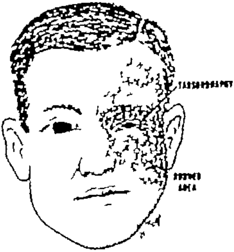


Fig. 57

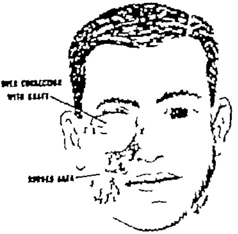


Fig. 58

Fig. 57 Diagram to illustrate the type of burn requiring a tarsorrhaphy When the burned area involves an appreciable amount of skin adjacent to both the upper and lower eyelids, a tarsorrhaphy must be performed to prevent contracture of the lids and ectropion formation. The tarsorrhaphy is carried out at the time a skin graft is applied.

Fig. 58 Diagrammatic outline to show the corrective procedure required when a third-degree burn is adjacent to only one eyelid. In this instance, there was a burn of the lower eyelid and the adjacent skin of the cheek. The upper eyelid was not involved Such configuration of burn does not require a tarsorrhaphy but an overcorrection of the lower eyelid is made when the initial skin graft is applied. Tarsorrhaphy is indicated if both eyelids are involved but if only one eyelid is involved, overcorrection with a graft is the procedure of choice.

stallation of an antibiotic ophthalmic ointment to prevent infection (see Chapter 10)

In full thickness burns of the eyelids, the chief danger is contracture and ectropion formation Incomplete closure of the lids causes drying of the cornea and ulcer formation If infection then supervenes, a panophthalmitis may develop The important aim in treating burns of the eyelids therefore is protection of the cornea As soon as the eschar is removed, grafting must be carried out in such a way as to prevent ectropion formation [6]

The procedure used to prevent contracture depends upon the amount of involvement of the surrounding skin (Figs 57 and 58) If the skin adjacent to the lower lid is burned and the skin adjacent to the upper lid is normal only the lower lid is likely to become contracted and *vice versa* In such instances, the affected lid should be overcorrected in such a way as to make allowance for a certain amount of inevitable contracture Sutures are placed along the margin of the lid and tension is applied An incision is made through the superficial tissue of the lid in order to release any contracture of scar tissue that may have occurred A thick split thickness or full thickness graft

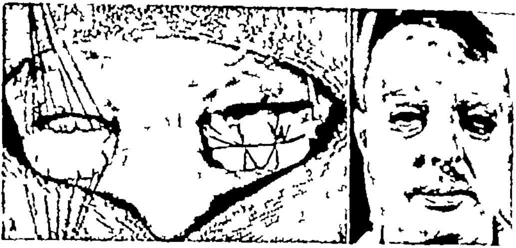


FIG. 59 *A* This patient sustained deep dermal burns of the entire face and eyelids six weeks prior to this photograph. There was contracture of both lower eyelids. After releasing these contractures, an overcorrection graft was applied. The graft on the right eye has been sutured in place and is ready to be dressed. A stent type dressing has been completed over the graft on the left lower eyelid.

B Both eyelids have healed completely The thick split-thickness skin grafts are quite evident. The graft did not contract hence a good functional and cosmetic result was obtained.

should be sutured in place A better take of graft occurs when a stent dressing is applied

In deep dermal burns, contracture of the lids sometimes occurs after epithelization Overcorrection with grafts is the acceptable corrective procedure (Fig. 59)

In more extensive burns about the eye involving both upper and lower eyelids a tarsorrhaphy must be performed at the time the graft is applied [5] Tarsorrhaphy is essential to prevent ectropion of both lids because of contracture of the surrounding skin Simple blepharorrhaphy does not suffice because the lids are pulled apart in a few days. The tarsorrhaphy must be of the tongue in groove type (Fig 60) This is carried out at the time the graft is applied A small peephole is left in the center of the lid The lids must not be separated for a period of about six months or contracture with ectropion formation will occur At this time they may be cut apart under local anesthesia (Fig. 61) The necessary reconstructive procedures are performed later

Burns of the Ears

Full thickness injury to the external ear results in destruction of the cartilage and subsequent infection As infection progresses, more cartilage is liquefied and an abscess of the auricle is formed The ai in such burns is to minimize infection and to p er tion of the cartilage The best method of tr if necessary early and wide incision of t

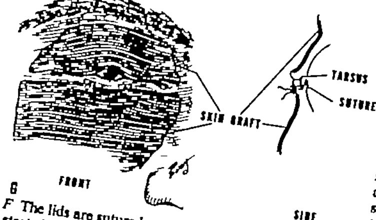
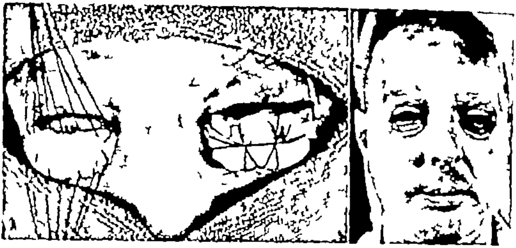


FIG 60 *E* Initial steps in technique of tongue in-groove type tarsorrhaphy Areas are prepared at *A B C* and *D* in order to use the tarsal plate on the upper eyelid as the tongue to be placed in a groove prepared in the lower eyelid. This makes an attachment of the lids on either side of the iris, allowing a peephole in the center After the sites are selected, the first step is to make small transverse incisions as shown in *A* A pair of scissors are used to remove a thin strip of epithelium between these incisions as shown in *B* A knife is used to separate the anterior and posterior layers of the lid as shown in *C* This separation on the upper lid is carried out anterior to the tarsal plate. Area *D* is then ready for suturing as shown in *F*

F The lids are sutured together with 00000 silk. A needle is placed on either end of the suture and the sutures are started from the posterior aspect of the lower lid. They are carried up through the posterior lip of the upper lid and out through the anterior portion of the lower lid. This brings the posterior portion of the upper lid (the part containing the tarsus) into the groove of the lower lid. The sutures are tied over a small piece of rubber catheter Excessive tension must be avoided.

G Skin grafts are applied after the tarsorrhaphy has been completed The split thickness skin should be placed near the margins of the lid and anchored in place with fine interrupted sutures. The sutures in the tarsorrhaphy may be removed between the eighth and tenth postoperative day



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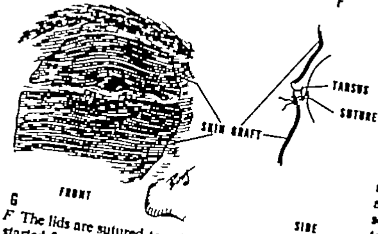

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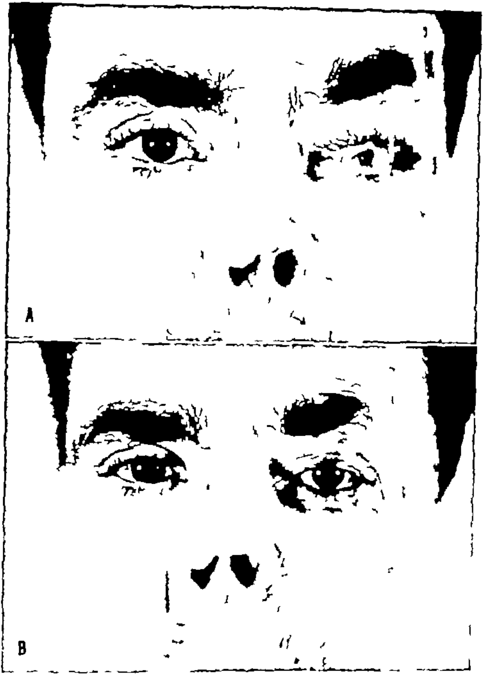

FIG. 61 *A* This patient experienced a very deep burn of the face in an aircraft accident. A tarsorrhaphy was performed on the lids of the left eye at the time of the initial grafting procedure. The tarsorrhaphy had been in place six months when this photograph was taken.

B Under local anesthesia, the lids have been separated by cutting tarsorrhaphy attachments with a scalpel. An additional reconstructive procedure may be necessary to lengthen the lower lid.

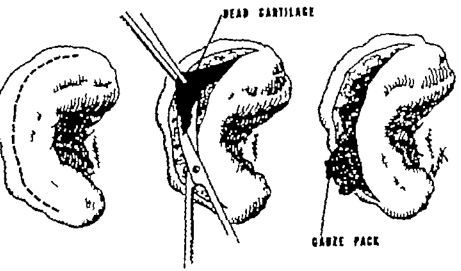

FIG. 62. In full-thickness burns of the ear the cartilage liquefies and becomes infected. Usually there is considerable edema of the auricle. The preferred method of treatment is a wide, fishmouth-type incision along the helix. The dead cartilage is removed and the two layers of the ear are held apart with a gauze pack. Wet dressings are applied and the gauze pack is changed each day. The ear heals by secondary intention.

mouth type of incision is made, beginning at the helix and extending down over the auricle. The devitalized cartilage may thus be exposed and removed (Fig. 62).

Free drainage can be accomplished by separating the anterior and posterior layers of the auricle with loose gauze packing and by applying warm wet compresses continuously. The warm compresses also alleviate pain. When the infection subsides the ear heals by secondary intention. In almost all full thickness burns of the ear, subsequent plastic reconstruction is required.

RESPIRATORY TRACT DAMAGE ASSOCIATED WITH BURNS

Respiratory tract damage is frequently associated with burns about the face and neck, especially in individuals burned in a closed space. Respiratory irritation results from inhalation of noxious fumes and gases. For clinical purposes, respiratory tract injury may be divided into two parts: damage of the upper respiratory tract, and damage of the lower respiratory tract (Fig. 63).

Injury of the upper respiratory tract includes irritation to the posterior pharynx, trachea and larger bronchi. Injury of the lower respiratory tract involves the alveoli. In all probability, an actual burn of the respiratory passages does not occur except in certain experimental situations.[2]

Inhalation injury is recognized clinically by redness and edema in the posterior pharynx, coughing, hoarseness and singeing of the

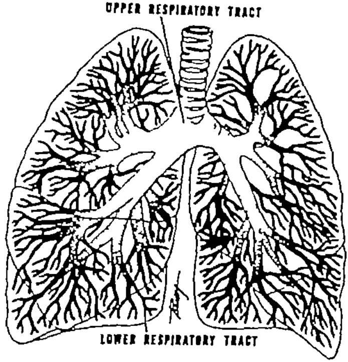

FIG 63 Diagrammatic outline of the respiratory tract. The clear areas show the upper respiratory tract, particularly the trachea and larger bronchi. If these areas are injured by the inhalation of noxious gases and fumes, a marked amount of secretion will result but these larger air passages can be kept free if a tracheotomy is performed. The heavily shaded areas represent the lower respiratory tract. Irritation of this area leads to damage in the alveoli. A tracheotomy is indicated in treatment however most patients who experience injury to the lower respiratory tract do not survive.

nasal hairs. Later signs are rales in the chest, dyspnea, and increased respiratory rate Increased bronchial markings may be apparent on roentgenographic examination (Fig. 64) In burns of the upper respiratory tract, profuse secretions may be present, and a secretional type of obstruction may occur unless a tracheotomy is performed promptly

Injury to the lower respiratory tract may produce (1) obstruction of the airway because of bronchial constriction congestion edema or desquamation (2) congestion of the alveolar walls or (3) pulmonary edema Any or all of these effects may markedly alter the resistance to breathing and result in serious hypoventilation

Appreciable injury to the lower respiratory tract is difficult to treat successfully Usually the patient s condition deteriorates rapidly until death occurs

Irrespective of the areas involved the treatment of respiratory tract damage associated with burns is the same Treatment consists of tracheotomy followed by diligent aspiration of tracheobronchial secretions and the administration of oxygen A tracheotomy must be performed as soon as respiratory tract damage is suspected The patient may suffer serious anoxia if tracheotomy is delayed until respira

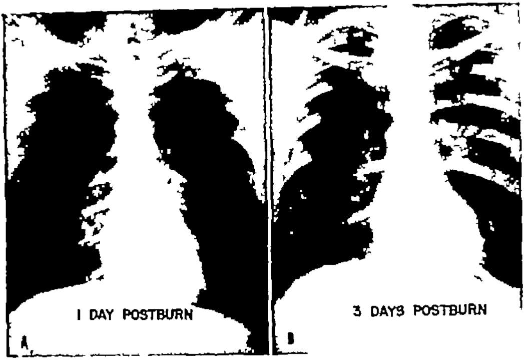

FIG 64 *A* Roentgenogram of the chest of a patient who was burned in a closed space when a mattress caught on fire. He received appreciable damage through inhalation. On the first day after the burn, there is only a slight increase in bronchial markings in the lung fields.

B The third postburn day Roentgenogram shows a marked infiltration and increase of hilar markings in both lung fields. A tracheotomy was performed on this patient as soon as he was admitted and he experienced an uneventful recovery It was believed that he had irritation of only the upper respiratory tract.

tory difficulty and cyanosis are present The use of positive pressure oxygen and antifoaming agents may be of value when the lower respiratory tract is affected.

THE USE OF TRACHEOTOMY IN BURNED PATIENTS

For a number of years tracheotomy was used mainly to treat established respiratory obstruction In recent years tracheotomy has been used increasingly as a prophylactic measure The three basic reasons for performing tracheotomy are to prevent or treat mechanical airway obstruction, to avoid asphyxia from retained secretions, and to facilitate the administration of anesthesia

An immediate tracheotomy is indicated in patients who have respiratory tract damage These patients are in danger of asphyxia both from swelling of the air passages and from accumulated secretions. The danger of hypoventilation is lessened if early tracheotomy is performed and efficient tracheobronchial toilet is maintained

Respiratory embarrassment may follow a severe burn of the neck in which there is edema of the pharyngeal mucosa and epiglottis, as well as the soft tissues of the neck. Some patients are unwilling to

Fig 65 After a tracheotomy anesthesia is easily administered to patients with deep burns of the face if the tracheotomy tube is replaced with a short endotracheal tube. The tube is inserted after the trachea has been sprayed with a local anesthetic agent.

cough because of discomfort others are unable to clear their respiratory passages spontaneously because of age extent of injury or debility A tracheotomy may be indicated in all of these patients in order to maintain an adequate airway

It is advisable to do an elective tracheotomy on all patients sustaining deep burns of the face Tracheotomy is usually performed within the first 12 to 24 hours following thermal injury It is much easier to perform a tracheotomy in burns about the head and neck as an elective procedure before extensive edema occurs. Tracheotomy lessens the danger of respiratory difficulty from mechanical or secretional obstruction

In addition, tracheotomy offers several advantages in administering anesthesia to patients who must have repeated operative procedures

1 The surgical field is free from anesthetic equipment

2. The danger of increasing damage to the burned surface from pressure or irritation is avoided Sometimes when an anesthesia mask is applied over face grafts or a recently healed partial thickness burn the area is converted to a deeper injury

3 Intubation is simpler by way of the tracheotomy opening. It can be accomplished in most instances after topical anesthesia of the

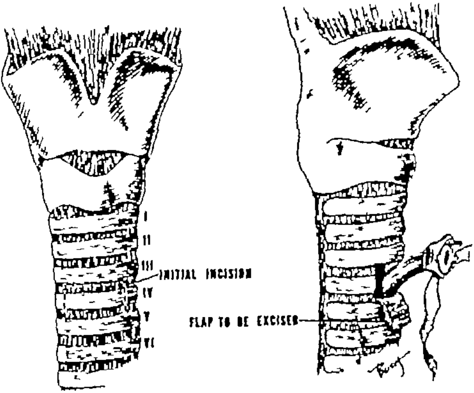

FIG. 66. An acceptable technique in the performance of tracheotomy A segment of the anterior tracheal wall is removed. As soon as the trachea is located, an inverted U-shaped incision is made beginning at the upper border of the fifth tracheal cartilage and extending across the fourth. The flap of the anterior tracheal wall is pulled out and a tracheotomy tube is inserted. The flap is then cut away using a scalpel and the tracheotomy tube is left in place. Removal of a small segment of the anterior tracheal wall gives assurance that the airway will be patent even though the tracheotomy tube slips out. It is easier to introduce an endotracheal tube for anesthesia providing a small segment of the trachea has been removed.

trachea, the use of deep anesthesia or muscle relaxants for intubation is thus avoided (Fig 65) It is usually difficult to insert an endotracheal tube through the mouth because of contracture Intubation through the nose is troublesome and may carry infection to the lungs

4 There is less difficulty from aspiration following anesthesia

Technique of Tracheotomy

Tracheotomy is carried out with better technique and more accurate placing of the cannula if it is performed as an elective rather than an emergency procedure. Either a vertical or transverse incision may be used The vertical incision offers better exposure if the tracheotomy must be carried out hurriedly A transverse incision is preferred if the operation is an elective one The optimal level for the tracheotomy opening is at the third to fifth tracheal ring.

A most important feature in technique is the excision of a segment of one of the tracheal cartilages (Fig. 66) Such an opening permits

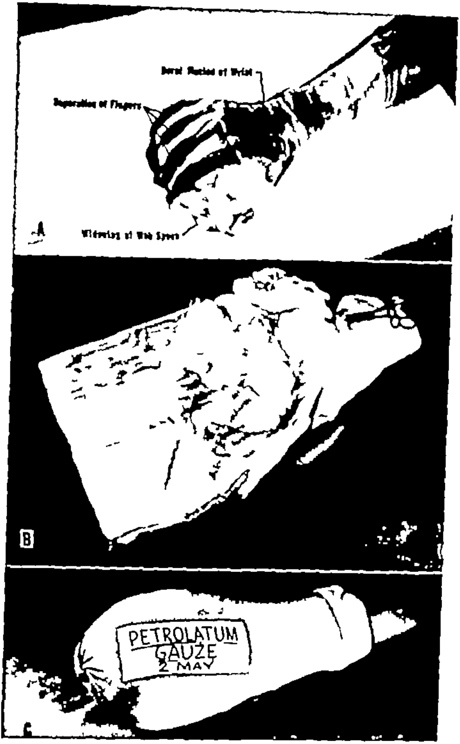

FIG. 67 *A* Initial step in applying an occlusive dressing to a burned hand. A layer of lightly impregnated gauze is placed over the burned area. The hand and forearm are put on two large abdominal pads. Fluffed gauze is placed on the palm of the hand in such a way that there is dorsiflexion of the wrist and acute flexion of metacarpophalangeal joints. The fingers are separated with gauze and special attention is given to maintaining the width of the webbed space between the index finger and the thumb.

B. Additional fluffed gauze is placed over the hand to make a large absorptive

easier insertion of the tracheotomy tube, it prevents the edges of the trachea from approximating in case the tube slips out, and it provides a patent opening for easier entry of the endotracheal tube during anesthesia Occasionally, it may be necessary to perform bronchoscopy through the tracheotomy opening Such a procedure is much easier if a segment of the anterior tracheal wall has been excised The excision technique causes no complications or delay in healing of the tracheotomy wound

A tracheotomy may do more harm than good unless careful attention is paid to proper aftercare The trachea and major bronchi should be aspirated frequently but gently Unnecessary trauma to the tracheal epithelium must be avoided (see Nursing Care, Chapter 10)

BURNS OF THE HANDS

Burns of the hands are common because of their exposed position and because the hands are used to combat the fire In wartime especially in airplane accidents, hands are often burned severely Individuals in the vicinity of explosions place their hands over their faces, thus flash burns of the dorsum of the hands are common

The most common type of burn of the hand involves the dorsum of the fingers, hands, and wrist Burns of the palm are less common

High priority should be given to early treatment of burns of the hands It is most important to obtain early skin coverage in this area in order to achieve a good functional result. The principles of initial local care applicable to all burns are also applicable to burns of the hands (see Chapter 4) Superficial and deep second-degree burns of the hands do well when treated by exposure The patient is encouraged to maintain his hand in a position of function until the crust is formed As soon as the crust falls off and new epithelium is formed beneath it, motion should be encouraged Although it may not be possible to maintain the hand in an ideal position during the entire period of treatment, the crust nearly always falls off within three weeks and immediate return of function is then possible If burns of the hand are treated on an outpatient basis, it is best to apply a large, bulky dressing (Fig. 67) Irrespective of whether second-degree burns of the hands are treated by exposure or by dressings, healing and return of function usually occur about the same time (Fig 68) Supervised active physiotherapy and whirlpool baths aid in the return of function

dressing. It may or may not be necessary to put a plaster splint in the dressing to maintain dorsiflexion of the wrist.

C The entire dressing is wrapped with even compression by means of an elastic bandage. Stockinette is placed over the dressing. Then the type of treatment and date applied is noted on the dressing.

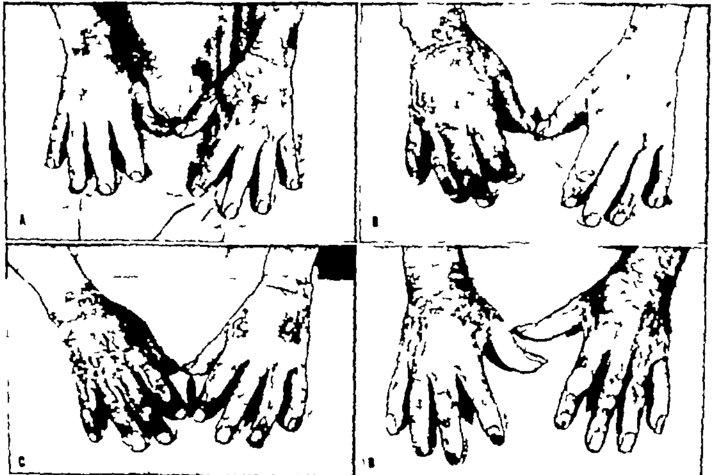

FIG 68 *A* Second-degree burns of the dorsum of both hands 12 hours after injury After cleansing the hands with soap and water all blisters have been removed. The right hand was exposed and the left hand was dressed with a large, occlusive dressing.

B The 5th postburn day The dressing has been removed from the left hand and a good protective crust has formed on the exposed hand.

C The 17th postburn day The dressing has been changed on the left hand and newly formed epithelium is visible over most of the area. The crust on the right hand is beginning to separate. One additional dressing was required for the left hand. The crust fell off the right hand on the 21st postburn day

D Photograph at time of discharge. Healing of both hands was comparable. The patient stated that the dressed hand was more comfortable for the first 48 hours thereafter the exposed hand was more comfortable. He preferred exposure treatment because he did not like the pain associated with multiple dressing changes.

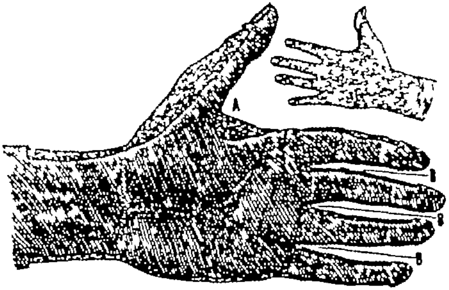

FIG. 69 Diagram of areas of excision for full-thickness burns of the dorsum of the hand. The small insert shows that dead skin of the dorsum of the hand has been removed. The lines of incision are shown on the drawing of the palmar surface. It is extremely important to excise the skin of the entire webbed space at *A*. Likewise, at *B*, the webbed spaces between the fingers should be excised even though they are unburned. Less contracture occurs in these areas if the webbed spaces are excised and covered with a graft.

Full thickness burns of the hands are best treated by massive occlusive dressings Dressings are preferred to exposure because (1) position of function is better maintained, (2) demarcation between second-degree and third-degree areas can be detected earlier, and (3) separation of the eschar is more rapid Dressings must be applied in such a way that there is moderate dorsiflexion of the wrist, moderate flexion of the fingers, and a position of abduction and apposition for the thumb Special attention should be given to maintaining the width of the webbed space between the index finger and the thumb (Fig 67, *A*)

The eschar should be removed as soon as practical If the area of full thickness burn can be well delineated, it should be excised as soon as the general condition of the patient permits [3, 4] The optimum time for definitive excision is between the first and fifth postburn day Surgical excision removes all dead tissue and grafting provides skin cover thereby avoiding the whole phase of natural slough separation granulation and especially fibrosis. The healing time is shortened and active exercises can be carried out on the hands as soon as the grafts are stable When conditions prevent early excision separation of the eschar should be hastened by wet saline soaks

Surgical excision is best carried out under tourniquet constriction since this provides a bloodless field for operation Before a tourniquet is applied the hand should be elevated and the blood forced proxi

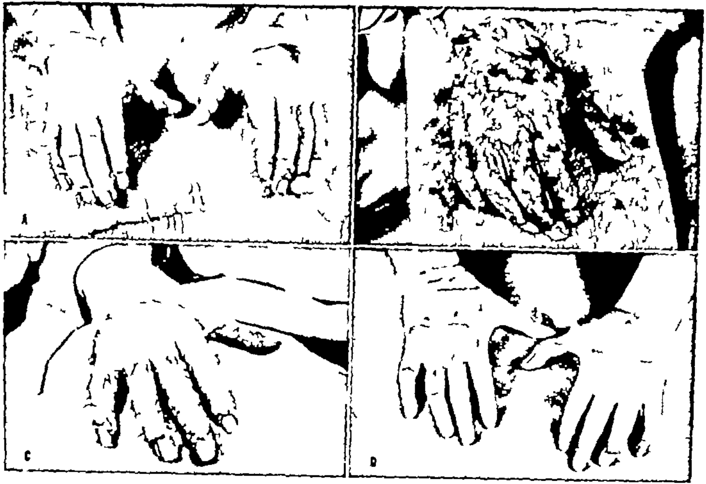

Fig. 70. *A* Full-thickness burns of the dorsum of both hands at 20 hours after injury

B The 3rd postburn day The dead skin of the dorsum of the hands was excised after the application of a tourniquet. The tourniquet was released and all bleeding points were ligated. An occlusive dressing was applied.

C The 5th postburn day A thick, split thickness graft has been sutured in place. Note that the webbed spaces have been excised and a graft has been placed in these areas on the right hand.

D Photograph at time of discharge. The function of both hands is excellent. A slightly better result was obtained on the right hand because the webbed spaces were excised. On the left hand, a slight contracture at the base of the fingers occurred because the unburned webbed spaces were not excised

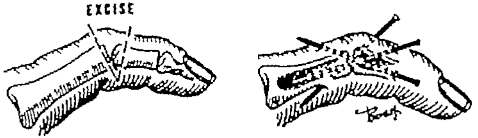

FIG 71 Diagram of technique for arthrodesis of interphalangeal joint in deep burns with pyarthrosis of the joint. The articular cartilages are excised and three Kirschner wires are placed through the finger and left in place until fusion occurs. This fixes the finger in a positon of function and prevents deforming flexion contractures.

mally by the use of an Esmarch rubber bandage If excision is performed early a plane of edema usually underlies the eschar and makes dissection easy The webbed spaces between the fingers and between the index finger and the thumb are seldom burned However, a better functional result is achieved if they are excised (Fig 69) The tourniquet is released after excision and all bleeding points are ligated A bandage is applied and grafting is carried out two to four days later

Split thickness skin is applied (015 of an inch in thickness) Strips of skin are first placed transversely over the metacarpal phalangeal joints, and small strips may then be added longitudinally over the fingers. Other strips are placed transversely across the dorsum of the hand When grafts are placed longitudinally on the back of the hand, the suture lines contract and interfere with function Grafts on the back of the hand must be carefully sutured in place and covered with a bulky, well-splinted dressing (Fig. 70)

Deep burns of the hand are very deforming unless active therapy is given The characteristic deformity is hyperextention of the metacarpalphalangeal joints and extreme flexion of the interphalangeal joints If extensor tendons or joints are involved several procedures are indicated in order to preserve maximum function Nonviable tendons are excised When pyarthrosis of the proximal interphalangeal joints with loss of the extensor tendon occurs, these joints must be fused in a position of function to prevent severe flexion contracture This procedure is carried out at the time of grafting. The articular cartilage is removed and flexion is maintained at approximately 30 degrees by the insertion of Kirschner wires (Fig 71) Fusion becomes solid in approximately four to six weeks, and the wires are then removed The extensor mechanism of the little finger is particularly weak Therefore, after burns of the little finger, a special effort must be made to prevent flexion contracture

In almost all full thickness burns of the hand atrophy and fibrosis

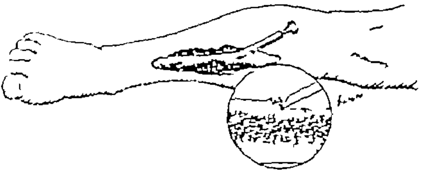

FIG. 72. Diagrammatic illustration for removal of dead bone after a severe burn. When the periosteum is burned, the outer cortex of the bone down to the marrow cavity must be removed. If this is chiseled away small granulating buds form from the marrow cavity and provide a surface upon which a graft may be placed.

of muscles occur especially in the thenar region The webbed space between the thumb and index finger is shortened unless special attention is directed toward maintaining the thumb in the appropriate position

Third-degree burns of the palm of the hand are not common When they do occur, immediate excision is not indicated As soon as a granulating surface is obtained it must be covered with thick split thickness skin After the grafts are healed active physiotherapy may be required for very long periods of time in order to achieve an optimal functional result

BURNS INVOLVING BONE

Sometimes a burn extends down to and includes the bone The burned soft tissue around the bone usually sequestrates and leaves a granulating surface The bone is dry and dead in appearance because of loss of periosteum The aim of therapy is to achieve a granulating surface over which a skin graft may be applied

As soon as the loss of periosteum is diagnosed and the surrounding eschar is removed multiple perforations may be made in the bone down to the marrow cavity Granulating buds may appear through the openings within two or three weeks Eventually a granulating surface appears and a skin graft may be placed on it In long bones, a surface for grafting may be achieved more rapidly if the outer dead bone is removed with a chisel (Fig. 72) Granulations form from the marrow cavity rather rapidly Within two or three weeks a skin graft may be applied (Fig 73)

In burns of the cranium it is usually advisable to put multiple holes in the external table (Fig. 74) The electric bone drill is of value in making multiple small perforations (Fig. 75) If the injury is very deep it may be necessary to remove the dead bone down to the dura

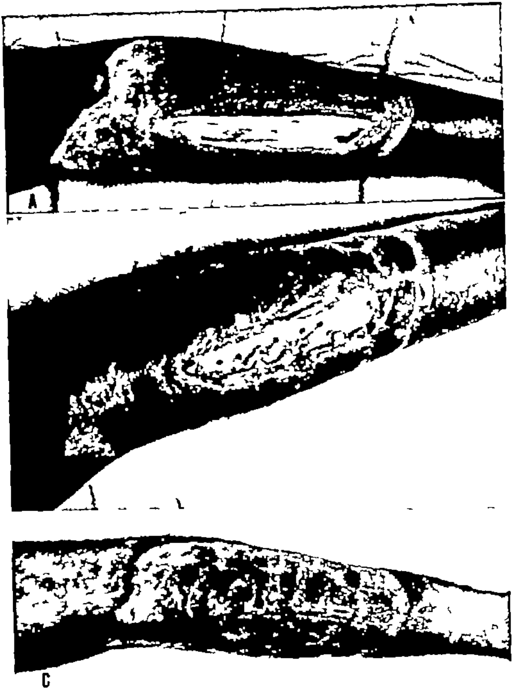

FIG. 73 *A* Deep burn of the anterior aspect of the lower leg involving the periosteum of the tibia. There is a granulating surface beside the tibia.

B. Multiple holes have been placed in the outer cortex of the tibia and a skin graft has been placed over the adjacent granulating wound A few granulating buds slowly appeared through the holes in the cortex. The entire outer cortex of the tibia was removed by means of a chisel and a graft was applied within a few days.

C The 130th postburn day The entire area on the anterior aspect of the leg is completely covered

FIG 74 *Very deep burn of the scalp and cranium sustained in an aircraft accident.* Most of the face has been grafted. Multiple holes have been placed in the outer table. Granulating buds appeared through these holes in most areas. It was necessary to remove the outer table by chisel in a few areas. As soon as a granulating surface formed, split-thickness grafts were applied.

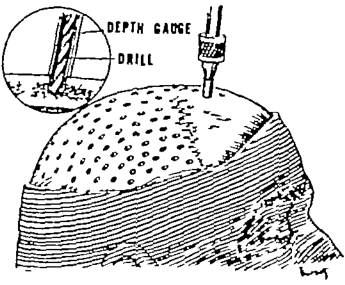

FIG 75 Diagrammatic illustration of the technique of placing multiple holes in the outer table of the skull after a deep burn of the periosteum. An electric bone drill is used. A depth gauge is placed over the drill to prevent the point of the drill from reaching the inner table. This procedure of putting multiple drill holes in the outer table is carried out as soon as the dead scalp is removed. A skin graft may be applied when granulation tissue is visible through these holes.

FIG. 76. A deep dermal burn of the left hand and a fracture of the middle third of the humerus sustained in an airplane accident. The fracture was treated by skeletal traction and the burn was allowed to remain exposed. A hanging cast was applied during the fourth week when the burn had healed. Burns complicated by simple fracture should be treated by exposure whenever possible.

(see Electrical Burns, Chapter 9) Granulating tissue will form on the dura and a skin graft can then be applied This gives immediate coverage to the area Reconstructive procedures are carried out later

BURNS COMPLICATED BY FRACTURES

A burn is occasionally complicated by an underlying fracture Such an injury should not be treated by the application of a cast. Burns complicated by fractures usually do well if skeletal traction is used for immobilization of the fracture and the burned area is treated by exposure (Fig. 76) In deep burns, the eschar should be removed as rapidly as possible As soon as the area is covered with a skin graft, plaster immobilization may be carried out

BURNS OF THE FOOT

Burns of the sole of the foot are relatively uncommon They occur occasionally when an individual walks through a burning area without shoes. Burns of the sole of the foot usually do well when exposed

A B

77 *A* Deep third-degree burn of the sole of the foot treated by exposure. A thick, split thickness graft was sutured in place after the eschar had been removed.

B Photograph taken three months after injury The thick split thickness graft served as a good cover for the wound.

They should not be excised As soon as the eschar sequestrates the area should be prepared for grafting. A split thickness skin graft (018 inch in thickness) is applied (Fig. 77) This procedure is generally satisfactory In some instances it may be necessary to cover the area with a full thickness skin flap at a later time

BURNS OF THE AXILLA

Deep burns of the axilla are almost invariably followed by severe contracture Such burns should be splinted with the arm in complete abduction until healing is complete

In full thickness burns the area should be excised down to the fascia as soon as the third-degree injury is well demarcated It is important to excise beyond the anterior and posterior folds These areas must be excised even though they are not burned The grafts are placed transversely across the anterior fold the axilla and the posterior fold and then sutured in place If lines joining the grafts occur along the edges of the anterior and the posterior folds these areas will contract and limit motion of the shoulder This difficulty is eliminated if the grafts are placed transversely and extend well beyond both folds As soon as the graft is applied the area must be dressed

and the arm must be held in abduction by means of a plaster splint Early motion and active physiotherapy are encouraged (see Figs 30, *D* and 30, *E*, p 88)

BURNS OF THE PENIS

When there is a burn of the penis an indwelling catheter should be inserted Full thickness burns in this area should not be excised As soon as a granulating surface is available, split thickness skin grafts are sutured in place in a circular fashion A firm dressing may be applied and held by means of an elastic bandage.

BURNS OF THE PERINEUM

Burns of the perineum are usually delayed in healing because of the surrounding moisture and infection They heal more rapidly when they are exposed Dressings in this area are most difficult and only make for a warm, moist environment which is conducive to infection

In full thickness burns, the recipient site is prepared by sitz baths or wet saline soaks The colon is cleansed with multiple enemas before grafting. After grafting, paregoric should be used to inhibit bowel movements for six or seven days Grafts applied to the perineum are held in place better by a stent dressing Immobilization of this area is very difficult The application of a body spica with the legs in lithotomy position is of value in some instances

In extensive burns, grafting of the perineum is postponed until most other areas are covered with skin Remarkable spontaneous healing of the perineum occurs frequently even though the burns first appear to be very deep Because of difficulties with proper immobilization grafts of the perineum often do not take as well as grafts in other areas For this reason, it is better to use available grafts first in areas where a good take is more likely to occur

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CHAPTER 7

The Problem of Infection

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DEFINITIONS

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In this discussion the term "septicemia" will mean a positive blood culture in combination with the signs and symptoms of invasion of the blood stream. In general septicemia is associated with persistently positive blood cultures. A focus of infection is always present. Microorganisms enter the blood stream from this focal point either continuously or at very frequent intervals. After vigorous antibiotic therapy has been given sometimes only the pretreatment blood culture is positive but clinical findings of blood stream infection persist. The diagnosis of septicemia is justified under this condition.

A clear-cut differentiation between "septicemia" and "bacteremia" is not always possible. The term "bacteremia" is used with reference to a transient blood stream infection. A positive blood culture may be obtained if a blood sample is taken at the proper time, but frequently the strong clinical impression of bacteremia cannot be substantiated bacteriologically. A focus of infection exists, but host defenses protect the blood stream from invading microorganisms. If the defenses are disturbed by trauma, microorganisms transiently gain access to the blood stream but are quickly disposed of by the natural defense mechanisms of the host.

The clinical features of septicemia and bacteremia are sufficiently characteristic to make a differentiation possible in most instances. This is important because septicemia and bacteremia have entirely different clinical meanings.

Local infection refers to the presence of microorganisms on a wound. While some investigators have insisted that inflammation must be present as a sign of tissue reaction to the bacteria if the term "infection" is used, the present definition purposely includes instances without evidence of tissue response. The term "suppuration" indicates that pus is present on a wound. It is the most common manifestation of local infection. "Sepsis" is an entirely nonspecific term that refers to infection in general.

Obviously much overlapping occurs between these various forms of infection. Local infection may become locally invasive and finally generally invasive. Local infection, with or without suppuration, may also occur in combination with generally invasive infection.

SOURCE OF INFECTION

At one time it was thought that full thickness burns were sterile initially and that they became colonized by bacteria only when inadvertent contamination occurred in the course of treatment. Studies of Price have refuted this viewpoint.[13] The intensity of heat and duration of exposure to heat may be so great that the full thickness of the skin is rendered nonviable, yet bacteria may survive deep in the

CHAPTER 7

The Problem of Infection

INFECTION is the cardinal problem in the treatment of burns. It is a cause of pain nutritional disturbances conversion of second-degree burns to third-degree burns failure of skin grafts to take and death

Widespread misconceptions exist concerning the importance of infectious complications Most of those who have had abundant experience in the treatment of burns agree that infection is extremely important. Others think that infection is an avoidable rare complication and therefore it should not pose a serious difficulty if a patient is treated properly These contrasting points of view may be resolved if it is understood that the term infection may include diverse clinical entities ranging from simple colonization of a wound by bacteria of low pathogenicity to invasive infection that proves fatal Unless the exact definition of infection is given all statements about its incidence, seriousness and importance are meaningless. Appropriate definitions are essential for the evaluation of therapy Systemically administered antibiotics, for instance may be lifesaving in septicemia caused by Group A beta hemolytic streptococci They may be useless, however, in the treatment of localized suppuration on a granulating wound.

The problem of infection differs somewhat in various parts of the world because of differences in climate types of patients, and methods of care Many significant contributions on infection in burns have been made in several clinics in recent years [3, 4, 5, 8, 9, 11, 12, 14]

DEFINITIONS

Infection may be classified broadly into two types invasive" and "local Invasive infection is further divided into locally invasive and generally invasive Cellulitis lymphangitis and regional lymph adenitis are examples of the former septicemia of the latter

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crypts of sweat glands and hair follicles. These bacteria are capable of rapid proliferation The bacterial count beneath the surface of an experimental full thickness burn increases in spite of any form of local therapy including the application of strong antiseptics Altemeier s clinical data are in accord with Price s experimental observations.[2]

A second important source of infection is contamination of wounds from the outside Bacteria may gain access to the wound from unsterile dressings unsterile instruments, or from the respiratory tract of the patient or of attendants

Although the therapeutic implication of these avenues of infection are described fully in Chapter 4 a few comments are pertinent It is obvious that an effective therapeutic approach to bacteria in the skin appendages cannot be found in local applications. The aims of therapy must consist of (1) protection from early invasion of the blood stream, and (2) early establishment of a tissue barrier against invasive infections Antibiotics can be given systemically in an effort to achieve the first aim Early excision of dead tissue and grafting may accomplish the second aim.

Contamination from the outside appears to have an entirely different interpretation, depending upon whether early local care is by occlusive dressings or by the exposure method If dressings are used contaminating bacteria cause an increase in the bacterial inoculum, which is harmful When the exposure method is employed successful treatment does not depend upon prevention of contamination—an utter impossibility—but on the fact that contaminating bacteria are rendered harmless by the dryness of the wound It may be argued that since the majority of the bacteria reside in the skin appendages the small additional number of bacteria introduced by contamination through the dressings is of no real importance This appears to be an unreasonable point of view Even if a certain amount of damage is inevitable, why should further preventable damage be introduced?

TIME SEQUENCE OF INFECTION

Septicemia, the most serious infectious complication is most common in the early postburn period (Fig. 78) Its incidence is very low when the wounds have progressed to a granulating stage The remarkable resistance of granulation tissue to invasive bacteria has long been recognized and is of crucial importance to an understanding of the rationale of burn therapy The principal therapeutic problem is to prevent septicemia prior to the time when a granulating barrier is established

Granulation tissue is an excellent example of local infection with

NATURAL HISTORY OF A THIRD DEGREE BURN WITH SURVIVAL

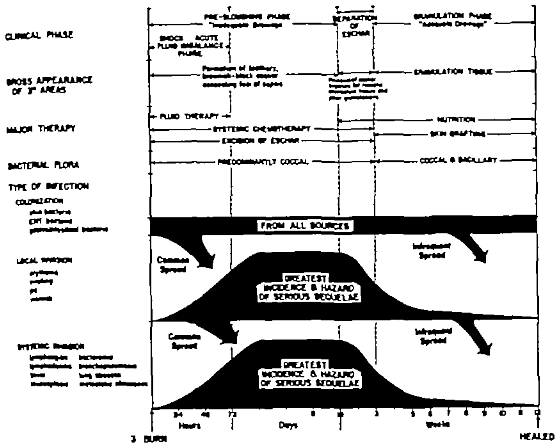

FIG 78. The natural history of a third-degree burn with survival. Note that the danger of invasive infection is greatest before separation of eschars has occurred In the presence of granulating wounds, invasive infection is rare.[11] This figure was constructed by Dr B. A. Barnes.

suppuration Invasive infection is very rare in the granulating stage, despite abundant suppuration

SEPTICEMIA

Septicemia is probably the most serious complication in burns In a recent survey of 61 deaths resulting from burns 50 per cent of the deaths were caused directly or indirectly by septicemia [3] This figure brings the magnitude of the problem into focus It also emphasizes that prevention of septicemia is a principal objective in the early care of a burned patient

On reading the literature prior to 1950 the impression is gained that septicemia rarely occurred and that its high incidence at present is a recent development This impression is only partially correct In much of the earlier literature data on blood culture were not given Therefore, it is quite likely that septicemia was seldom diagnosed for the simple reason that no cultures were taken to determine its pres-

ence On the other hand, it is probable that recent improvemen fluid therapy have made possible longer survival of severely bu patients and as a result more patients now survive until such a *as septicemia is likely to occur*

Predisposing Factors

Septicemia occurs most frequently in patients who sustain tensive, full thickness burns It is a complication of partial thick burns only rarely but occasionally it may be present when t burns are very extensive

The extent and depth of burn are important factors affecting only the incidence of septicemia but also the prognosis the larger deeper the burn the less likely the success of therapy Old age a poor *nutritional status* are probably associated with an incre incidence of septicemia and a less favorable prognosis Data are available on this point at present.

Source of Invading Bacteria

There is no evidence that the incidence of septicemia differ burned patients treated properly by dressings or in patients tre properly by the exposure method Most evidence favors the viewp that invading microorganisms originate at the wound and thence g access to the blood stream Almost without exception the same spe of microorganisms are cultured from the blood and the wou Liedberg was able to carry out bacteriophage typing on *M pyoge* from three patients and the *M pyogenes* strains cultured from blood and the wounds were of the same type [13]

In hemorrhagic shock in dogs Fine and his co-workers presen evidence that bacteria from the gastrointestinal tract may invade blood stream [6] In the burned patients in whom septicemia was served, however hypotension did not precede the onset of septice but followed it In some patients who have both septicemia and hy tension gastrointestinal bacteria may invade the blood stream ter nally In the majority of patients, the primary source of bacteria pears to be the burn wound

Bacteriology

The definitive diagnosis of septicemia cannot be made withou blood culture Precise bacteriologic information is essential not o for diagnosis but also for appropriate antibiotic therapy Althou the clinical diagnosis of septicemia is frequently correct a clini diagnosis without bacteriologic data is a totally inadequate basis rational therapy

A blood sample should be taken from a carefully prepared unburned site If an unburned area is not available for venipuncture, the blood sample may have to be drawn by puncture through the burn Such samples are meaningful only if they yield no growth, since it is impossible to be sure whether growth resulted from infection of the blood stream or from contamination A good bacteriologic routine should be used such as that described by Liedberg [10] Antibiotic sensitivity testing of isolated microorganisms is an essential part of the bacteriologic study

Micrococcus pyogenes (Staph aureus) and various gram negative rods are the predominant causative microorganisms They occur with about equal frequency, although *M pyogenes* is somewhat more common Of the gram negative microorganisms, *Pseudomonas* and *Proteus* species are most frequently found, other coliform species are encountered but less frequently Recovery of two or more species from the blood stream at the same time is not uncommon

Clinical Features

1 The temperature is usually high (104° to 107° F rectally) Marked fluctuations in temperature do not occur as a rule The temperature is rarely below 102° F even though antipyretics and cold sponging are employed

2 The pulse is rapid and regular It tends to be of good quality and becomes thready only when hypotension develops The electrocardiogram shows a sinus tachycardia (rate 140 to 170 per minute) Carotid sinus stimulation produces only a transient slowing of the heart rate and digitalis does not affect the rate significantly

3 Hypotension and oliguria occur in severe cases

4 Paralytic ileus is a common and most distressing finding. It prevents gastrointestinal feeding and thus contributes substantially to debilitation

5 Disorientation occurs in a variable degree Its severity tends to parallel the height of the fever

6 In severe cases, there is a bleeding tendency manifested by petechiae, ecchymoses, and oozing from the wounds.

7 Mild jaundice may be observed (total serum bilirubin 2 to 4 mg. per cent)

The onset of septicemia may be insidious or acute. A gradual rise in temperature is often the earliest manifestation, the complete septicemia syndrome then develops gradually within two or three days A blood culture is indicated in any burned patient whose rectal temperature is 103° F or higher If a high fever persists, repeated blood cultures must be obtained At times the clinical course of a patient

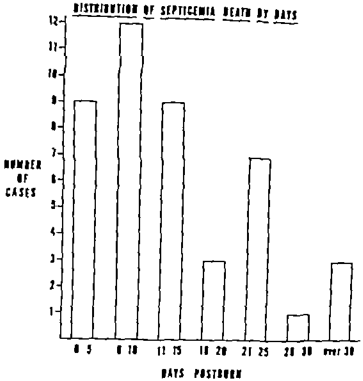

FIG. 79 Bar graph showing distribution of 44 deaths associated with septicemia at Brooke Army Hospital, Brooke Army Medical Center Most of the deaths occurred within the first 15 postburn days while the eschar was intact or sloughing

may be quite satisfactory and then—suddenly and without warning—all the signs of septicemia become evident

Although septicemia may occur at any time during the postburn period, a few generalizations may be pertinent. Septicemia is most common during the first fifteen days following thermal injury but quite rare after a month (Fig. 79) In 7 patients who had septicemia and survived, the mean time of onset was the sixth postburn day In all but one of these patients, septicemia was diagnosed within the first ten days, in one case the diagnosis was not made until the eleventh day Considering the 44 deaths and 7 survivors together the onset of septicemia occurred within the first 10 days in 53 per cent of the cases

The peak occurrence of septicemia in the early postburn period can be explained by the absence of local defenses against invading bacteria during this time As soon as granulation tissue appears septicemia is controlled rather easily The time required for the growth of good granulation tissue varies It depends upon the patient s metabolic response the type of local therapy given the adequacy of nutritional support, and probably many other factors Patients who develop septicemia after three weeks either fail to grow granulation tissue or experience destruction of this previously formed barrier

The sudden, mysterious disappearance of apparently healthy granulations within a period of a few days is one of the most discouraging occurrences in the treatment of a severe burn Since the disappearance of granulations and the onset of septicemia are almost simultaneous occurrences, it is impossible to ascertain which is the cause and which the effect However it seems reasonable to suppose that impairment of the granulating barrier against infection creates a condition that facilitates invasion of the blood stream

Laboratory Data

Multiple blood cultures may be necessary before a positive one is obtained Sudden leukopenia is often an early warning signal Leukocytosis with a shift to the left is common The excretion of urinary sodium is generally very low, regardless of the sodium intake. Soroff observed that a precipitous decrease in the urinary sodium may precede clinical recognition of septicemia [16] If there is severe oliguria, a patient frequently experiences progressive azotemia and hyperkalemia. Hemolysis occurs in varying degrees and is manifested by a rapidly decreasing hemoglobin concentration an increased serum bilirubin concentration (mostly in the indirect fraction), and an increased excretion of urobilinogen in urine and feces

TREATMENT OF SEPTICEMIA

An accurate bacteriologic diagnosis is essential for proper treatment Therapy is sufficiently difficult when detailed bacteriologic information is available but it is virtually hopeless when it must be administered blindly

Antibiotics

Microorganisms isolated from blood cultures should be tested for sensitivity to several antibiotics If they are resistant to the commonly used antibiotics, sensitivity testing should include such antibiotics as bacitracin neomycin, polymyxin B, and cathomycin One or more antibiotics to which the invading microorganisms are sensitive *in vitro* should be given in large doses preferably intravenously If penicillin and streptomycin are given prophylactically during early therapy invading bacteria are generally resistant to these agents The tetracycline compounds and chloramphenicol may be effective against some strains of *M pyogenes* and against coliform bacilli Polymyxin B is the drug of choice against microorganisms of the *Pseudomonas* species. Bacitracin, chloramphenicol cathomycin and erythromycin may be useful in the therapy of septicemia due to *M pyogenes*

Although bacitracin has a definite nephrotoxic action its use in large doses (100 000 to 300 000 units per day) is indicated if the septicemia is due to a microorganism that is sensitive to bacitracin but resistant to other antibiotics *in vitro* The aim in antibiotic therapy is to diminish the load of bacteria in the blood stream and to prevent formation of abscesses in internal organs until wound care eliminates the wound as a feeding focus

Wound Care

Wound management is extremely important but very difficult The dry appearance of a burn wound frequently leads the inexperienced to conclude that no infection is present. However, dry and benign-appearing eschars may actually obscure active bacterial proliferation and abundant suppuration that is often occurring beneath them

The care of a burn wound depends upon the status of the wound at the time septicemia develops All efforts should be directed toward the elimination of eschar followed by wound coverage in such a way that further insult is not added to the patient. Extensive surgical excision under general anesthesia produces more trauma than can be tolerated by a patient having septicemia. If the third-degree eschar covers less than 15 per cent of the body surface, excision may be justified. In more extensive burns, wet soaks are applied every four hours At each change of wet dressing, every effort should be made to remove some of the dead tissue The removal of dead tissue is performed with forceps and scissors in such a way that bleeding is minimal. This aggressive approach to the elimination of dead tissue hastens the formation of granulation tissue and, since little trauma occurs it permits earlier coverage If the eschars are boldly excised further invasion of bacteria may occur via lymphatic and vascular channels

Skin should be applied as soon as a suitable surface is obtained Autografts may be applied if the burn is of moderate size and the patient is in good condition In more extensive burns homografts should be applied at the bedside without anesthesia (see "Removal of Eschars and Homografts Chapter 5)

Sometimes septicemia occurs when spontaneous sequestration of the eschar is well under way Granulation tissues are being formed but they have not yet developed sufficiently to afford good protection against invasive infection Profuse suppuration is characteristic of such wounds. If septicemia occurs at this stage the prognosis is somewhat better than when the eschar is firmly attached Local application of antibiotics in large quantities may substantially reduce

the bacterial population on the wound, and the number of microorganisms gaining access to the blood stream may be reduced sufficiently to enable body defenses to cope with them

In the discussion of the onset of septicemia, it was mentioned that well-established granulations occasionally disappear Any treatment applied locally is comparatively unsuccessful, and the only real hope lies in preventive therapy Disappearance of granulations may be prevented by energetic administration of supportive measures and application of some skin grafts during the first two weeks

Supportive Therapy

Oxygen is indicated in patients who have marked tachypnea and tachycardia. Administration by mask is the preferred method

Nasogastric suction should be used if abdominal distention is marked

Aspirin and tepid sponging are recommended when the temperature rises to 103° F or higher

Digitalis is indicated only in the presence of heart failure Acute left ventricular failure with pulmonary edema is a common terminal event If pulmonary edema occurs, rapid digitalization is indicated, but successful relief is rarely obtained. The drug has no effect on the tachycardia in the absence of heart failure

Cortisone and *hydrocortisone* are contraindicated (see Chapter 8) These hormones have been recommended as adjuvants to specific antibiotic therapy in the management of certain infections in which the patient s life is endangered by the toxic manifestations of infection In such a combined hormone-antibiotic regimen, the hormones are used to suppress toxic manifestation while the antibiotics have an opportunity to kill the offending microorganisms Specific antibiotic therapy that will kill all invading microorganisms is rarely available for the treatment of burns complicated by septicemia If the infection is to be overcome the patient's own defense mechanisms must combat the invading microorganisms. The problem of severe toxic manifestations of infection following thermal injury is not limited to a few days but may persist for weeks. The rarity of adrenocortical insufficiency is discussed in Chapter 8 In a burned patient, the known deleterious effects of the hormones in decreasing the body s resistance to infection far outweigh the possible beneficial effects that might be expected from hormone therapy

Blood transfusions may be lifesaving. Transfusion requirements vary greatly the amounts of blood required depend upon the hemolytic properties of the offending microorganism One or two daily

transfusions are often necessary to maintain a normal hemoglobin concentration.

Fluid and electrolyte administration is important Since the problems of septicemia following thermal injury are critical any gross errors in fluid therapy must be avoided Frequent measurements of plasma electrolyte concentrations and the nonprotein nitrogen concentration are essential guides to therapy Gastrointestinal fluid losses and all urine excreted should be measured and analyzed for sodium, potassium and chloride content. The losses of these ions must be replaced quantitatively An additional allowance must be made for losses of sodium and chloride through sweat The water requirements—often quite high in uncomplicated extensive burns—may be extraordinarily high if septicemia is present Five to seven liters of free water are not an unusual daily requirement in order to maintain adequate clinical hydration

Norepinephrine infusions are definitely useful in the treatment of hypotension due to septicemia The hypotension of septicemia is caused by an intense vasodilation In contrast, the hypotension occurring during the initial 24 to 48 hours after a burn is caused predominantly by hypovolemia due to fluid losses rather than to vasomotor changes Thus norepinephrine is specifically indicated for the treatment of hypotension of septicemia but not during the initial replacement therapy If septicemia occurs norephinephrine must be infused at a rate to maintain blood pressure at a normal level If septicemia can be controlled by means of antibiotics and other therapy norepinephrine dosage is gradually decreased until the blood pressure can be maintained without administering the drug All too frequently however septicemia progresses, the norepinephrine requirement increases progressively, eventually even enormous doses fail to maintain the blood pressure and death ensues

Nutritional supportive measures are of utmost importance Effective nutritional support is often prevented by gastrointestinal atony that precludes oral and intragastric feeding Intravenous feedings must then be relied on but this procedure is far from adequate Vitamins should be given in large doses (see Chapter 8)

To recapitulate, it appears likely that antibiotic therapy and judicious wound care are the most important factors in the treatment of septicemia following thermal injury However all of the supportive measures mentioned may play decisive roles under special circumstances It is well to remember that many a patient has recovered whose condition appeared to be hopeless Regardless of how desperate the clinical picture may appear a defeatist attitude is never justified

PROGNOSIS IN SEPTICEMIA

There is ample evidence that the extent of burn and, more specifically, the extent of full thickness burn is the dominant factor influencing prognosis. A group of investigators at Brooke Army Medical Center reported that the mean extent of burn in 31 fatalities associated with septicemia was 56 per cent, 38 per cent being third degree The mean extent of burn in seven survivors was 42 per cent, 27 per cent being third degree.[3] Survival is rare in patients having third-degree burns covering 50 per cent of the body surface On the basis of limited data, it appears that a relatively small decrease in extent of burn may be associated with a profound decrease in the case fatality rate

The following hypothesis is proposed as an explanation of the problem of septicemia in burns When the cumulative case fatality rate is plotted as a function of the extent of burn, an S-shaped curve is obtained By appropriate transformation it can readily be shown that this curve has the essential features of a dosage-fatality curve commonly encountered in bio-assays Some of these curves have a characteristically rapid rise in mortality in the central portion Thus, only a small increase in dosage may result in an enormous increase in the case fatality rate From the similarity of the extent of burn fatality function and the dosage fatality function in bio-assays it may be reasoned that extent of burn acts in a manner analogous to dosage

When it is recognized that death following burns is frequently due to septicemia it is reasonable to assume that the dosage phenomenon is related to the number of pathogenic microorganisms gaining access to the circulation If large numbers of bacteria enter the blood stream continuously host defenses become exhausted and eventually they are overwhelmed. If the number of invading bacteria is not too large, host defenses can cope with them successfully providing both specific and nonspecific therapy is utilized until local barriers are formed against invasive infection

Although this concept may be somewhat oversimplified it forms an effective basis for the planning of therapy Efforts are directed not only at ridding the blood stream of invading microorganisms but also at reducing the bacterial inoculum causing persistence of septicemia Reduction of the feeding inoculum is the chief aim not only in removal of the eschar but also in the local use of antibiotics and in grafting Since only a slight margin may exist between the body's successful defense against invading microorganisms and its failure, supportive measures must be viewed not as minor adjuvants to other therapy but as an essential component that may make the difference between survival and death

BACTEREMIA

From clinical observations bacteremia is a frequently suspected diagnosis in burns but it can rarely be substantiated bacteriologically Bacteremia is often suspected if a sudden transient increase in temperature occurs after a dressing change In considering the definition of bacteremia a high incidence of bacteriologic confirmation would not be expected because body defenses rapidly clear the blood stream of the small showers" of invading microorganisms. Bacteremia may occur in third-degree burns even after the formation of a good granulating barrier If this condition occurs, it is usually caused by unduly rough treatment of the granulations Microorganisms may gain access to the blood stream when the integrity of granulations is impaired by mechanical trauma

LOCALLY INVASIVE INFECTION

Locally invasive infection is manifested by clinical signs such as cellulitis lymphangitis and regional lymphadenopathy Fever and leukocytosis are generally present Group A beta hemolytic streptococci are the cause of this type of infection in most instances.

In contrast to septicemia—a primary problem in extensive full thickness burns—locally invasive infection often complicates partial thickness burns of minor extent. This type of infection presented a very serious problem prior to the availability of antibiotics that are highly effective against streptococci Uncontrolled streptococcal sepsis proved fatal in many instances It is difficult for a young physician to appreciate the magnitude of the streptococcal problem in the era preceding the introduction of the sulfonamides.

Locally invasive infection is quite rare if prophylactic penicillin therapy is given If prophylactic penicillin therapy is not given and such an infection occurs, administration of penicillin results in prompt control of the infection Elevation and rest of the affected part are indicated When infection occurs it is common for partial thickness skin loss to be converted to full thickness skin loss. Prophylaxis is therefore of considerable importance

Partial thickness burns are often surrounded by a halo of edema and erythema due to first-degree burns This erythema may be confused with cellulitis and, conversely cellulitis may be mistaken for a first-degree burn The presence of an unexpected degree of fever leukocytosis pain or regional lymphadenopathy favors a diagnosis of cellulitis At times it is impossible to differentiate between cellulitis and a first-degree burn Then it is best to give large doses of penicillin on the assumption that a streptococcal cellulitis is present

Streptococci may be present on wounds and destroy viable epi

thelium long before there is any clinical indication of streptococcal infection This is an important reason for taking cultures of a burn wound at frequent intervals.

LOCAL INFECTION

The clinical implications of local infection are quite different from those of generally invasive infection Local infection does not threaten survival except in isolated and preventable instances Nevertheless, local infection has very serious consequences that contribute substantially to the patient's discomfort, metabolic derangements, and length of time required for complete healing.

Partial-Thickness Burns and Donor Sites

In wounds of this type, infection may cause partial thickness skin loss to become converted to full thickness skin loss If the burn is of the deep dermal type, even a small amount of local infection may destroy the remaining viable epithelium One advantage of the exposure method over occlusive dressings seems to be a more frequent, spontaneous healing of deep dermal burns as a result of better control of infection As a consequence, the need for skin grafting is decreased

The principles of early local care by the exposure method and by occlusive dressings are discussed in Chapter 4 However restatement of a few points is pertinent. The successful use of the exposure method in second-degree burns results in the formation of a dry crust Before the crust is fully formed, progressive drying of the exudate and exposure of the wound to a relatively cool environment prevent multiplication of microorganisms that contaminate the burn wound

It should be noted that an inevitable feature of treatment by exposure is the contamination of wounds by all bacteria in the patient s environment. Various microorganisms may be cultured from the surface of the crust but bacteria on the surface of a crust should be ignored just as bacteria obtained from the outer surface of a dressing are disregarded

By contrast an important factor in the treatment of second-degree burns by the occlusive dressing method is the avoidance of contamination. The size of the contaminating inoculum is probably important in determining whether or not suppuration may be avoided

If suppuration occurs by either method of local care there is great danger of full thickness skin loss This is one circumstance when the use of locally applied antibiotics may be beneficial

Extensive infection of donor sites may be a catastrophe Infection of donor sites may convert a relatively small third-degree burn into

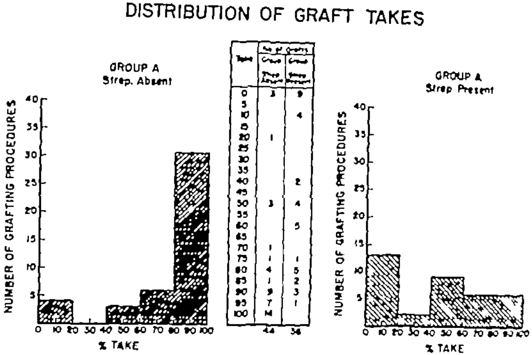

FIG 80 Distribution of graft takes on burn wounds colonized by Group A beta hemolytic streptococci and on burn wounds not colonized by streptococci. *Variation in takes is strikingly different. The deleterious effect of these streptococci on graft takes is unique.*

very extensive full thickness skin loss For this reason an essential aspect of treatment is detailed attention to donor sites (see Chapter 5) Infected donor sites may also be an indication for local application of antibiotics

All microorganisms that commonly colonize burn wounds appear to be capable of causing suppuration and destroying viable epithelium. However there is evidence that Group A beta hemolytic streptococci are unusually destructive Consequently, prophylactic antibiotic therapy is essential in the treatment of burns regardless of the type of local therapy employed Systemically administered penicillin is preferred

Granulating Wounds

Controversy exists over the significance of infection of granulating surfaces However when there is a dearth of specific information controversy is to be expected [10]

Many different types of streptococci may colonize a granulating wound However only Group A beta hemolytic streptococci cause widespread destruction of grafts (Fig. 80) The emphasis on Group A is important Streptococci that cause beta hemolysis on blood agar plates but do not belong to Lancefield s Group A are apparently

no more harmful than other microorganisms that may colonize a wound[11] Streptococci that produce alpha hemolysis and nonhemolytic streptococci do not appear to affect graft takes

It will be recalled that Group A beta hemolytic streptococci occupy a unique position in the pathogenesis of disease (rheumatic fever, glomerulonephritis) Their deleterious effect on graft takes is probably exerted through the production of the enzyme streptokinase which catalyzes the formation of the fibrinolytic enzyme plasmin This enzyme destroys the fibrin lattices by which grafts first adhere to a wound Certain streptococci other than those of Group A produce streptokinase, but these microorganisms are seldom found on burn wounds.

It is fortunate that Group A beta hemolytic streptococci are always sensitive to penicillin and usually they are also sensitive to other antibiotics If a culture from a wound yields beta hemolytic streptococci resistant to penicillin, it is almost certain that these bacteria do not belong to Group A

The following microorganisms are often isolated on cultures from granulating wounds *Micrococcus pyogenes* (Staph aureus), *Pseudomonas aeruginosa*, *Proteus vulgaris*, other enteric bacteria such as *Escherichia coli* and *Aerobacter aerogenes*, diphtheroids, and clostridia There is no conclusive evidence that these microorganisms differ in pathogenicity as gauged by fever, amount of suppuration, or effect on graft takes Even though these microorganisms are present, good graft takes occur providing the inoculum is small

Jackson and co-workers presented evidence that *Ps aeruginosa* caused graft failure,[9] an effect that Liedberg and co-workers failed to observe in their patients[13] *Ps aeruginosa* frequently colonize burn wounds and rarely affect the take of grafts In fact the preferred method for eliminating *Ps aeruginosa* is to apply a skin graft. Acetic acid soaks are of little value against *Pseudomonas* as the acid does not kill the microorganism but only decolorizes it

It is reasonably certain that grafts would take better on bacteria-free granulations than on contaminated surfaces If the bacterial species colonizing the wound are not of critical importance however what aspect of local infection of granulations is responsible for some of the graft failures? This may be answered, at least in part, by clinical experience Wounds on which suppuration abounds are poor recipient sites for grafts, whereas wounds that are largely free of suppuration generally are good recipient sites A crucial factor in determining the take of a graft may be the size of the bacterial inoculum and the rate of bacterial growth rather than the particular microorganisms involved

These considerations greatly simplify the preparation of granulating surfaces for grafting. Clinical criteria are the primary basis for determining the readiness of a wound for grafting The only essential bacteriologic information concerns the presence or absence of Group A beta hemolytic streptococci Grafting must not be performed if these microorganisms are present If other bacterial species are present it is of no special importance providing the wound appears clinically ready for grafting (see Chapter 5)

ANTIBIOTIC THERAPY FOR GRANULATING WOUNDS. *Systemically* administered antibiotics are of value during the grafting procedure only because they afford protection against streptococci They are probably of no value in the treatment of *wound suppuration caused* by other microorganisms. There is no conclusive evidence that systemically administered antibiotics alter the wound flora qualitatively or quantitatively except with respect to streptococci

It is customary to give procaine penicillin intramuscularly (600 000 units) once a day for two days for streptococcal prophylaxis before a dressing change or a grafting procedure and for two days thereafter Tetracycline (1 gm. daily) is also effective If a wound becomes infected by Group A beta hemolytic streptococci, vigorous treatment must be instituted to eliminate these microorganisms. They can *spread from wound to wound with amazing rapidity* and unless the staff is vigilant an epidemic of streptococcal wound infection may occur If streptococci suddenly appear on wounds, it is wise to obtain nose and throat cultures from the attending personnel visitors, and other patients to determine whether anyone is a carrier Vigorous penicillin treatment of carriers is indicated

Although Group A beta hemolytic streptococci are always sensitive to penicillin and the drug diffuses freely into the exudate of granulations, elimination of streptococci is not always achieved by means of penicillin In some instances, the failure of penicillin therapy appears to be due to its inactivation by *penicillinase that is produced* by other microorganisms present on the granulating surface The most efficient method of eliminating streptococci from a burn wound is by a combination of systemic and local antibiotic therapy Penicillin should be given intramuscularly for this purpose Tetracycline or chloramphenicol ointment should be applied locally every two days. Intramuscular penicillin may be replaced by tetracycline (2 gm daily by mouth) Systemic therapy should be continued for two days *after* a graft has been applied At least one negative culture for streptococci should be obtained *f* grafting. Con a common misconception, *clinical* *a) not sugg* infection by streptococci It is there l to make a cteriologic

study of all burn wounds Streptococci may prevent the take of grafts even when their presence is not suspected

The value of antibacterial substances applied locally to granulating surfaces has not been established Liedberg conducted a study with a 1 per cent chloramphenicol ointment a furacin soluble dressing, and corresponding control preparations Chloramphenicol seemed to be effective in eliminating some microorganisms but it failed to prevent infection caused by others No significant alteration in wound flora was noted as a result of treatment with a furacin soluble dressing. Although the qualitative bacteriologic difference between treated and control wounds was not striking, graft takes were significantly better on wounds treated with chloramphenicol and furacin than on control wounds. The observation of improvement in graft takes on the treated wounds may point towards reduction in the total bacterial population as a result of application of the antibacterial agents.[13] Further studies conducted by other investigators under slightly different experimental conditions have failed to show any difference in graft takes between control areas and areas treated with several different chemotherapeutic agents [7] It appears that results similar to those with local antibiotic therapy might be achieved by reduction in the bacterial population by means of more frequent dressing changes.

The disadvantages of local antibacterial therapy include development of resistant strains the expense of the active agents and the danger of development of an allergy Allergic reactions to systemic administration of penicillin are particularly common after local use of this antibiotic In addition penicillin is rapidly inactivated by penicillinase produced by the bacteria that abound on almost all granulating surfaces Either systemic or local manifestations of an allergy appear to be exceedingly rare when other antibacterial agents are employed

Agents commonly used for local therapy include the tetracycline compounds chloramphenicol bacitracin neomycin, polymyxin B and furacin Polymyxin B was used by Jackson and co-workers with good results when a wound was colonized by *Pseudomonas* [9] Furacin is inexpensive but it does not produce complete protection against Group A beta hemolytic streptococci [13] Nearly all agents tested up to the present have antibacterial effectiveness for only about 48 hours By that time only minimal concentrations remain on the wound surface because of absorption into the circulation or into the dressing

Some general conclusions may be formulated in regard to local antibacterial therapy

1 Local therapy is indicated for the elimination of Group A beta hemolytic streptococci

2. Local therapy is indicated for the treatment of infected second degree burns and infected donor sites Under these conditions, selection of an antibiotic is determined by *in vitro* sensitivity of the infecting microorganisms For optimal effectiveness, the drug should be applied at intervals not exceeding 48 hours

3 Local therapy may be indicated at the dressing change 24 to 48 hours prior to grafting for the purpose of reducing the bacterial population and assuring the elimination of beta hemolytic streptococci

4 In preparing a very dirty wound for grafting, local antibiotic therapy may reduce the time and the number of dressing changes required to obtain a surface that is suitable for grafting.

5 Granulating surfaces may be ready for grafting at a time when no donor sites are available As the donor sites heal the dressings over the granulating surfaces must be changed periodically During this period, local antibiotic therapy may decrease the frequency of required dressing changes.

Factors Other Than Infection Influencing Graft Takes

Although emphasis has been placed on the effect of microorganisms on graft takes it should not be concluded that the only factor influencing the fate of a graft is the bacterial flora of a wound The bacterial flora may be a decisive factor at times at other times however it is of little importance (see Chapter 5)

In the take of a graft it is important to consider the time of application Grafts show a good take when applied to fresh granulations during the second and third postburn weeks Graft takes become progressively worse in the succeeding weeks. A graft often shows a very poor take when it is applied months after injury It is not uncommon to find that grafts show a 100 per cent take during the first month The take of those applied during the next six weeks may be only 80 per cent and the take of those applied still later may be only 40 per cent. As time from injury progresses scar tissue at the base of the granulating wound increases and exerts a deleterious effect on graft take In any event the success of takes in the early postburn period furnishes an additional argument in favor of early grafting

SUMMATION OF THE PROBLEM OF INFECTION

In 1933 Aldrich first suggested that the toxemia of burns was a toxemia of infection [1] This suggestion has been amply supported in recent years by careful bacteriologic observations As fluid therapy has become increasingly effective in preventing death during the im

mediate postburn period, invasive infection has become an increasingly common cause of death The use of potent antibiotics has altered the types of infection encountered, but it has not solved the problem of infection Hemolytic streptococcal sepsis—often lethal in the presulfonamide era—can now be combated and prevented One of the most serious threats to survival of burned patients is septicemia caused by microorganisms other than hemolytic streptococci, many of which are resistant to antibiotics. Thus infection has become the cardinal problem in the treatment of burns

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CHAPTER 8

Metabolic Response and Nutrition

THE METABOLIC alterations initiated by a burn are dramatic. Although much remains to be learned about these alterations, a large amount of important information has been accumulated during the past 25 years In the discussion that follows some pertinent experimental and clinical data are reviewed They form the foundation on which rational therapy is based

PROTEIN METABOLISM

The normal adult is in nitrogen equilibrium. Intake equals excretion, and the total quantity of protein stores remains essentially stable. If the nitrogen intake is greatly increased positive nitrogen balance may occur for brief periods of time but the normal adult does not have the capacity for sustained protein storage It should be noted that there may be nitrogen equilibrium (1) when protein anabolism and catabolism are decreased, and (2) when protein anabolism and catabolism are increased The condition necessary for equilibrium is that the rates of anabolism and catabolism remain equal

Since nearly all the available information on protein metabolism in burns is based on balance experiments this interpretation is essential for proper understanding of the data Negative nitrogen balance implies that the rate of catabolism exceeds the rate of anabolism but yields no information about the absolute rate of either process Similarly positive nitrogen balance implies that the rate of anabolism exceeds the rate of catabolism Some inferences can be made about the kind of tissue changes that are taking place when in addition to nitrogen balance, information is available about the balances of other predominantly intracellular constituents such as phosphorus and potassium [21]

After the ingestion of protein, the amino acids entering the circulation mix rapidly with amino acids formed by catabolism of body proteins A part of this mixture is oxidized to urea and excreted another part serves as building stones for protein synthesis In health, these processes are well integrated and, although the rates of exchange are rapid, a delicate balance is maintained Balance studies yield no information about these dynamic aspects of protein metabolism

Nitrogen Balance

In the early postburn period strongly negative nitrogen balance is characteristic of severely burned patients because of large nitrogen losses and low nitrogen intake

INCREASED EXCRETION OF URINARY NITROGEN Increased urinary excretion of nonprotein nitrogenous products is characteristic This may not be evident in the first few postburn days because of poor renal function The high excretion of urinary nitrogen is nearly always evident in three to five days and tends toward a maximum between the first and second postburn weeks Thereafter the urinary nitrogen decreases progressively it is often low after a month, sometimes being extremely low A normal adult ingesting an average diet excretes 10 to 15 gm of urinary nitrogen per day Approximately 90 per cent of this nitrogen is in the form of urea In burned patients, urinary nitrogen excretion may increase to more than 30 gm per day

The magnitude of urinary nitrogen excretion varies greatly and cannot be predicted in an individual patient, but a few generalizations are pertinent

1 There is a rough correlation between the severity of the burn and the amount of nitrogen excreted, the more extensive the burn, the larger the nitrogen excretion

2 Preburn body weight is positively correlated with nitrogen excretion

3 Men generally excrete more than women

4 Usually the increased nitrogen excretion does not occur in patients who were malnourished before injury

Most of the nitrogen in burned patients is excreted as urea as in normal subjects On rare occasions a substantial fraction of the urinary nitrogen consists of nonprotein nitrogenous products that do not normally appear in the urine [22] No definite identification of these substances has been made Attention is called to the fact that this excretion pattern is exceptional Probably these unidentified products occur only in very deep burns that are complicated by extensive muscle necrosis.

In the past most studies on burned patients were concerned with gross abnormalities of over all nitrogen excretion Recently alterations in the excretion of certain amino acids have been studied in detail [7, 19] Although these data are difficult to interpret they point the way for future investigations

NITROGEN LOSSES THROUGH THE WOUND EXUDATE The amount of nitrogen lost by this route is highly variable but may account for a large fraction of the total nitrogen losses. In second-degree burns the nitrogen of the exudate tends to be high in the early postburn period but declines rapidly as the wounds heal In third-degree burns with extensive granulating wounds the exudate nitrogen is well correlated with the amount of suppuration The loss of 5 to 7 grams of nitrogen into the exudate per day is not uncommon in such burns This is one reason why early wound closure is of paramount importance

LOW NITROGEN INTAKE In addition to increased losses low nitrogen intake contributes substantially to negative balance This has a less decisive influence on balance in the early postburn period than increased excretion

The duration and magnitude of negative balance is influenced by the severity of the burn as well as by the nutritional regimen used The generalizations stated in connection with nitrogen excretion are also pertinent here Negative balance is more intense and longer in the extensive burns than in small burns it is more intense although not necessarily longer in men than women and it is transient or absent in patients who were malnourished before injury An energetic nutritional regimen instituted seven to ten days after burning, comprised of a high protein and high caloric diet, may reduce substantially the duration of negative nitrogen balance Unless special efforts are made to achieve ingestion of such a diet negative balance in a severe burn can be expected to last for approximately a month

After a month the well treated patient returns to nitrogen equilibrium or positive balance Urinary excretion is generally low at this time and nitrogen intake tends to be increasing. In contrast to the early postburn period when much of the ingested nitrogen is oxidized to urea and excreted efficient utilization of ingested nitrogen is the rule Some of these changes are illustrated in Figure 81

Plasma Proteins

Marked changes in the concentration of plasma protein occur as a result of two factors (1) the loss of proteins through the wound and (2) alterations in the metabolism of plasma proteins

The proteins of blister fluid and lymph have been studied in detail by Cope and his co-workers [3] Human blister fluid has an average pro-

tein content of 4 0 gm per 100 ml with a higher albumin/globulin ratio than plasma Escape of the smaller albumin molecules presumably occurs more readily through the damaged capillaries than escape of the larger globulin molecules. Qualitatively similar changes have been observed in the lymph draining from burned extremities of dogs Direct loss of proteins via the exudate explains in part the characteristic plasma protein changes in the early postburn period Pronounced hypoalbuminemia and hyperglobulinemia are present Vigorous intravenous therapy with plasma or albumin tends to diminish the hypoalbuminemia but cannot compensate for it completely because of persistent losses The loss of albumin rich fluid into the wound is the most potent evidence favoring plasma as initial replacement therapy (see Chapter 3)

Mild hypoalbuminemia and hyperglobulinemia tend to persist until wound healing is complete The increase in the serum globulin is due chiefly to an increase in the gamma globulin fraction [20] Large intakes of protein fail to increase the serum albumin to normal Usually the extent of abnormal plasma protein concentrations is directly related to the severity of injury the more severe the injury the greater the abnormality

Because the liver occupies a cardinal role in protein synthesis it is logical to look for derangements in liver function as an explanation of the observed protein changes The cephalin-cholesterol flocculation test and the thymol turbidity test are abnormal in many patients the incidence and degree of abnormality varying with the extent of injury Bromsulfalein retention is quite common.[12, 16] In fatal cases varying degrees of structural changes of liver parenchyma have been observed. These changes consist of cloudy swelling, sinusoidal congestion fatty infiltration and, in some instances frank necrosis. It is important to emphasize that liver cell necrosis—once believed to occur only after therapy with tannic acid—can also occur in severe burns in the absence of treatment with hepatotoxic agents like tannic acid To what extent the functional and histologic abnormalities in the liver of burned patients represents a specific effect of the burn cannot be assessed at present. Sepsis a complication of severe burns, may also cause changes in the liver

Anemia

The red cell mass deficit resulting from erythrocyte destruction in the immediate postburn period is discussed in Chapter 3 In some patients, a frank hemolytic anemia occurs This anemia is manifested by a rapidly decreasing hematocrit hyperbilirubinemia, and increased

In the past most studies on burned patients were concerned with gross abnormalities of over all nitrogen excretion Recently alterations in the excretion of certain amino acids have been studied in detail [7, 19] Although these data are difficult to interpret they point the way for future investigations

NITROGEN LOSSES THROUGH THE WOUND EXUDATE. The amount of nitrogen lost by this route is highly variable but may account for a large fraction of the total nitrogen losses In second-degree burns, the nitrogen of the exudate tends to be high in the early postburn period but declines rapidly as the wounds heal In third-degree burns with extensive granulating wounds the exudate nitrogen is well correlated with the amount of suppuration The loss of 5 to 7 grams of nitrogen into the exudate per day is not uncommon in such burns This is one reason why early wound closure is of paramount importance.

LOW NITROGEN INTAKE In addition to increased losses low nitrogen intake contributes substantially to negative balance This has a less decisive influence on balance in the early postburn period than increased excretion

The duration and magnitude of negative balance is influenced by the severity of the burn as well as by the nutritional regimen used The generalizations stated in connection with nitrogen excretion are also pertinent here Negative balance is more intense and longer in the extensive burns than in small burns, it is more intense although not necessarily longer in men than women and it is transient or absent in patients who were malnourished before injury An energetic nutritional regimen, instituted seven to ten days after burning comprised of a high protein and high caloric diet may reduce substantially the duration of negative nitrogen balance Unless special efforts are made to achieve ingestion of such a diet negative balance in a severe burn can be expected to last for approximately a month

After a month the well treated patient returns to nitrogen equilibrium or positive balance Urinary excretion is generally low at this time and nitrogen intake tends to be increasing. In contrast to the early postburn period when much of the ingested nitrogen is oxidized to urea and excreted efficient utilization of ingested nitrogen is the rule Some of these changes are illustrated in Figure 81

Plasma Proteins

Marked changes in the concentration of plasma protein occur as a result of two factors (1) the loss of proteins through the wound and (2) alterations in the metabolism of plasma proteins

The proteins of blister fluid and lymph have been studied in detail by Cope and his co-workers [3] Human blister fluid has an average pro-

tein content of 4 0 gm per 100 ml with a higher albumin/globulin ratio than plasma Escape of the smaller albumin molecules presumably occurs more readily through the damaged capillaries than escape of the larger globulin molecules Qualitatively, similar changes have been observed in the lymph draining from burned extremities of dogs. Direct loss of proteins via the exudate explains in part the characteristic plasma protein changes in the early postburn period Pronounced hypoalbuminemia and hyperglobulinemia are present Vigorous intravenous therapy with plasma or albumin tends to diminish the hypoalbuminemia but cannot compensate for it completely because of persistent losses. The loss of albumin rich fluid into the wound is the most potent evidence favoring plasma as initial replacement therapy (see Chapter 3)

Mild hypoalbuminemia and hyperglobulinemia tend to persist until wound healing is complete The increase in the serum globulin is due chiefly to an increase in the gamma globulin fraction [20] Large intakes of protein fail to increase the serum albumin to normal Usually the extent of abnormal plasma protein concentrations is directly related to the severity of injury the more severe the injury the greater the abnormality

Because the liver occupies a cardinal role in protein synthesis, it is logical to look for derangements in liver function as an explanation of the observed protein changes The cephalin-cholesterol flocculation test and the thymol turbidity test are abnormal in many patients, the incidence and degree of abnormality varying with the extent of injury Bromsulfalein retention is quite common [12, 16] In fatal cases varying degrees of structural changes of liver parenchyma have been observed. These changes consist of cloudy swelling, sinusoidal congestion fatty infiltration and in some instances, frank necrosis It is important to emphasize that liver cell necrosis—once believed to occur only after therapy with tannic acid—can also occur in severe burns in the absence of treatment with hepatotoxic agents like tannic acid. To what extent the functional and histologic abnormalities in the liver of burned patients represents a specific effect of the burn cannot be assessed at present. Sepsis a complication of severe burns, may also cause changes in the liver

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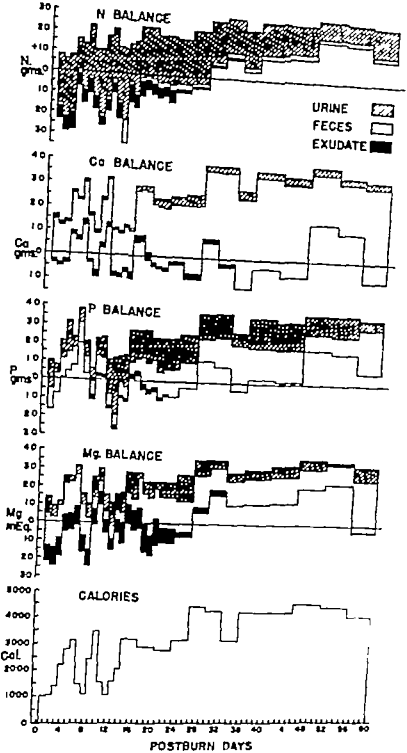

FIG 81 The intake is charted from the zero line upward and the output from the top of the intake line downward. Shaded areas below the zero line indicate negative balance clear areas above the zero line indicate positive balance The contributions of urine, feces, and exudate to the output are indicated by different shading

This 32-year-old man had partial-thickness burns of 70 per cent of the body surface. Nitrogen balance was strongly negative in the early postburn period because of the small intake and large excretion, both in the urine and the exudate. Gradually the appetite improved as evidenced by sustained high levels of nitrogen and caloric intake. The

urinary and fecal urobilinogen excretion Such a fulminant hemolytic process is nearly always associated with septicemia (see Chapter 7)

In addition, a chronic anemia is invariably associated with deep, extensive burns This anemia is due partially to blood loss from the wounds and donor sites and partially to impaired hematopoiesis The latter factor is probably of dominant importance in most cases James recorded decreased hemoglobin synthesis as measured by the incorporation of N^{15} labeled glycine into the heme of hemoglobin. He also noted an increased urinary excretion of free erythrocyte proto porphyrin hypoferremia, and hypercupremia [11, 12] These changes are reminiscent of many different kinds of anemia including the anemia of chronic infection

Osteoporosis

Osteoporosis is generally considered as a disturbance in protein metabolism due to failure of normal formation of the osteoid matrix In burns there are two factors that are known to be associated with osteoporosis (1) increased adrenocortical activity, and (2) prolonged immobilization

Osteoporosis is a well known complication of Cushing's syndrome, a disease characterized by excessive secretion of hormones of the hydrocortisone type [1] In large doses, this steroid has a definite tendency to induce negative nitrogen balance Albright has postulated that this effect is induced by the inhibition of protein anabolism (anti anabolic effect) [1] Insofar as bone is involved in this general metabolic abnormality insufficient quantities of osteoid are formed and osteoporosis results

Prolonged immobilization is a well-documented cause of osteoporosis [6] Stress and strain on bone serve as a normal stimulus for osteoblastic activity resulting in osteoid formation Osteoporosis follows immobilization because the normal stimulus for bone formation is not present

The extent of osteoporosis in burns is related to the severity of injury and to the length of immobilization The more severe burns are also associated with more intense and more prolonged hyperadrenocorticism.

Negative calcium and phosphorus balances have been noted in all patients on whom detailed studies have been made (Fig. 81) [21] High

urinary nitrogen decreased. After a month, the wounds were almost completely healed. Nitrogen balance became positive after 28 days and remained so throughout the duration of the study The degree of positive balance observed towards the latter part of the study was particularly striking when nitrogen retention rates reached a maximum of 20 gm. per day During periods of strongly positive balance, the urinary nitrogen was often very low despite a large nitrogen intake.

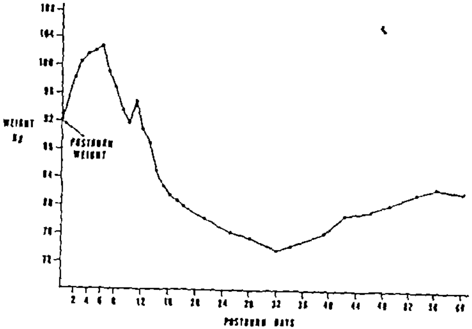

FIG 82. Characteristic weight curve of a severely burned patient.

intakes of calcium phosphorus, and vitamin D increase the excretion of calcium and phosphorus but fail to influence the negative balance of these minerals Such high intakes are potentially harmful because they cause a large urinary excretion of calcium and phosphorus and thus favor the development of renal calculi and nephrocalcinosis. These complications are rare but do occur occasionally (see Chapter 11) It is advisable to avoid unnecessary immobilization and to encourage patients to move about in bed as soon as the grafts are sufficiently well secured (see Nursing Care Chapter 10)

BODY COMPOSITION CHANGES

Water

During the early postburn period a rapid gain in total body water occurs because of the therapy that is essential for survival Most of the data obtained thus far indicate that the increase is limited chiefly to the extracellular fluid and appreciable cellular edema seldom occurs in properly treated patients Water intoxication—a clinical manifestation of severe cellular edema—is an avoidable complication (see Chapter 3)

The configuration of a characteristic weight curve is shown in Figure 82 The rapid early weight gain is a reflection of water gain and obscures the fact that decreases in the fat and muscle mass occur simultaneously Immediately following the maximum weight the early descending limb of the weight curve usually has a more gentle slope than the ascending limb preceding the maximum This is due to

delay in the excretion of edema fluid Clinical observations have pointed towards a rapid rate of water loss in the early postburn period This is indicated by the large volumes of water required by patients in order to prevent water depletion (see Chapter 3)

Muscle Metabolism

One of the most striking features of a severe burn is rapid muscle wasting. This clinical observation has been substantiated by balance studies[21] Figure 83 is constructed so that an approximate visual estimate can be made about intracellular changes The chart is another type of presentation of the balance data shown in Figure 81 In the upper portion of the chart, nitrogen and various minerals are charted in their normal intracellular proportions It should be recalled that calcium is found chiefly in bone and only in very small quantities in muscle On the other hand, phosphorus occurs in substantial amounts both in bone and in muscle The correlation between the nitrogen and intracellular phosphorus balance may be obtained by visually subtracting the observed calcium from the observed phosphorus balance in an algebraic manner For example in Period 4 both the calcium and phosphorus balance are negative The intracellular phosphorus balance is therefore represented by the small difference between the calcium and phosphorus balances and this difference is noted to be less negative than the observed nitrogen balance In Period 5 the phosphorus balance is positive while the calcium balance is negative Algebraic subtraction of a negative value from a positive value yields a large positive value In this period it is seen that the intracellular phosphorus balance obtained in this way corresponds well with the observed nitrogen balance

If all the changes in nitrogen balance could be explained by muscle catabolism or anabolism, the correlation between nitrogen and mineral balances should be excellent throughout a study such as that depicted in Figure 83 Some of the poor correlations are undoubtedly due to experimental errors but errors do not account for most of the discrepancies observed.

The following conclusions were reached in a detailed analysis of 10 long term studies of the type shown in Figure 83

1 The sweeping changes in nitrogen balance are accounted for in large measure by muscle catabolism and anabolism in the various phases of the natural history of a burn

2. During the period of negative nitrogen balance usually a sizable nitrogen loss occurs over and above that which may be explained by the loss of other intracellular constituents The source (or sources) of this extra nitrogen loss is obscure.

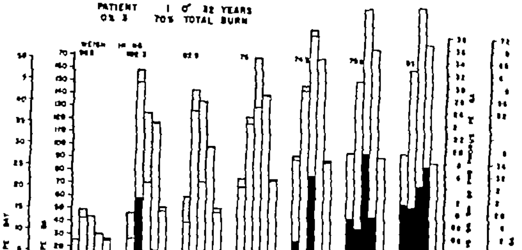

FIG 83 The intake is charted from the zero line up and the output from the top of the intake line down. Solid black areas indicate negative balance below the zero line and positive balance above it. The cross-hatched areas represent exudate contribution to the output. The relative contributions of urine and feces to the output are not shown. The data are charted on the basis of average per day. Four ordinate scales are applicable to the five elements charted in the upper portion. One gram of nitrogen is charted as equivalent to 3.3 mEq of potassium and 1/15 gm of phosphorus. Calcium and phosphorus are charted in a ratio of 2 1 "Magnesium times 10" and phosphorus are charted on the same ordinate scale. The reasons for this charting procedure have been given elsewhere [21]

3 One of the outstanding features of metabolic convalescence is that nitrogen retention does not cease when the nitrogen losses incurred during the early postburn period have been replaced. Patients may store nitrogen consistently for months after complete replacement of previous losses. This unusual phenomenon is undoubtedly

due to endocrine changes, but the details of these changes are not understood

Potassium

Except for minor discrepancies, nitrogen and potassium balances are usually well correlated after the first ten days (Fig 83)

The first 30 days may be divided into three rather distinct phases

1 In the first two or three postburn days, a striking outpouring of potassium usually occurs During this time, correlation with nitrogen losses may be good In some patients, the early urinary potassium losses may far exceed the amount expected by nitrogen losses

2. Starting on about the fourth or fifth postburn day, potassium retention commensurate with the potassium intake is usually observed At this time, potassium and nitrogen balances are completely dissociated *The potassium balance is often positive, and the nitrogen balance is nearly always negative* In this phase of positive potassium balance, the serum potassium concentration tends to be low A marked shift of potassium from the extracellular fluid to the intra cellular fluid undoubtedly occurs

3 After the initial negative balance and the subsequent positive balance, potassium balance usually becomes negative again in severe burns and then remains negative until the nitrogen balance becomes positive In this third phase, the level of potassium intake has little influence on potassium balance The body behaves as though it were saturated with potassium and excretes an amount equivalent to the intake plus the amount of potassium liberated by protein catabolism If the burn is of relatively small extent and nitrogen balance becomes positive shortly after injury, this third phase may not be observed

Fat

Extraordinarily large fat losses may occur The magnitude of the estimated losses depends on the method used in obtaining the esti mate and the severity of the injury In general data based on periodic measurement of total body water and on comparison between observed weight changes and weight changes predicted by nitrogen balance are in agreement.[18, 21] In a severely burned patient, the early fat loss may average as much as 600 gm. per day Minimal fat losses have been computed in smaller burns The amount of body fat metabolized depends on the nutritional regimen used An energetic feeding regimen tends to diminish losses, it is doubtful, however, whether any reasonable feeding program can completely prevent them By some unknown mechanism the severe burn increases the body's energy requirement to an enormous extent

Fat losses do not appear to cease when nitrogen balance becomes positive Persistent fat losses in the presence of strongly positive nitrogen balance have been estimated to occur [21] This curious combination of findings indicates that negative caloric balance is not incompatible with highly efficient protein synthesis. Why fat losses should persist so long into the convalescence is not known This problem in its entirety deserves further study

ENDOCRINE CHANGES

The metabolic alterations described previously are undoubtedly influenced by changes in hormonal balance Some changes have been recorded in the function of many of the endocrine glands on which studies have been made Unfortunately the metabolic abnormalities elicited by balance studies cannot be explained by changes in the known function of various endocrine glands The over-all metabolic response to a burn is exceedingly complex The problem is obscured not enlightened by attempting to ascribe this response to hyper function or hypofunction of any single endocrine gland

Adrenal Glands

The characteristic triad of the alarm reaction of Selye is often seen in burns adrenocortical hyperplasia lymphoid tissue involution and acute gastrointestinal ulcerations Increased secretion of steroid hormones of the hydrocortisone type cause the lymphoid involution It has not been determined whether the acute gastric and duodenal ulcers (Curling s ulcers) that frequently complicate severe burns are related to increased adrenal activity to a nonspecific effect of the stress of burning, or to some unknown factor (see Chapter 11)

The steroid excretion pattern is quite characteristic During the first three to seven days the urinary excretion of 17 ketosteroids is at the upper limit of normal or higher Thereafter the excretion decreases precipitously and remains low for a very long time [5] Increased excretion of cortin occurs as a rule and cortin excretion tends to remain high for long periods of time [4] Cortin is a group of substances that has biologic activity resembling hydrocortisone More recently increased excretion of "corticoids has also been noted [8] [4] Urinary assays for alderosterone have not been reported in burns

The 17 ketosteroid excretion reflects the adrenal and gonadal secretion of anabolic steroids (N hormone of Albright) [1] Testosterone is the prototype of this group of hormones The early increase of the urinary ketosteroids may be due to the metabolic transformation of hydrocortisone like steroids to substances that are excreted as 17 ketosteroids Subsequently the sustained low level of 17 ketosteroid

excretion may reflect impaired synthesis of N hormone by the adrenals, decreased testicular function, or both A low secretion of N" hormone by the adrenals and testes may contribute to the early negative nitrogen balance, but this is probably only one of the many hormonal factors involved During the period of positive nitrogen balance the excretion of 17-ketosteroids usually remains low If steroid secretion and direction of balance were causally related at this time, the steroid excretion would be expected to be high

The effect of hydrocortisone-like steroids on nitrogen metabolism is very complex In general, the administration of ACTH cortisone and hydrocortisone in large doses induces increased urinary nitrogen excretion This results in negative balance unless the nitrogen intake is increased substantially It is still a moot question whether this effect is produced by an action that inhibits protein anabolism (anti anabolic) or an action that increases the rate of protein catabolism The net alteration produced by the steroids may depend on many factors including nutritional state and the level of the protein intake of the patient. There is some evidence suggesting that the effect of steroids on protein metabolism may be different in different proteins such as muscle and liver protein Therefore, the correlation between nitrogen balance and steroid excretion is difficult to interpret

Failure to obtain straight forward, readily interpretable correla tions does not necessarily imply that altered adrenal function may not play a dominant role producing the observed alterations in nitrogen balance It does mean that the metabolic response to burns is so complex that the interrelations between endocrine changes and balances are not apparent at the present time

The difficulties encountered in relating nitrogen balance to changes in adrenocortical activity may be illustrated by what has been called the permissive action" of the adrenocortical hormones [9] It has been shown that, if adrenalectomized rats are given maintenance doses of adrenal extract they excrete increased amounts of nonprotein nitrogen in the urine after a fracture in a manner similar to control animals This increased excretion fails to occur when saline is given instead of the adrenal extracts Obviously fracture in these adrenalectomized animals could not cause increased secretion of adrenocortical hormones, yet the characteristic response occurs in terms of nitrogen excretion. Similar experiments have been performed with burns

The following conclusions appear justified at the present time

1 Severe burns are characterized metabolically by profound alterations in nitrogen balance and steroid metabolism

2. Since steroids are known to influence protein metabolism it is quite possible that alterations in nitrogen balance and steroid excretion are related causally

Fat losses do not appear to cease when nitrogen balance becomes positive Persistent fat losses in the presence of strongly positive nitrogen balance have been estimated to occur [21] This curious combination of findings indicates that negative caloric balance is not incompatible with highly efficient protein synthesis Why fat losses should persist so long into the convalescence is not known. This problem in its entirety deserves further study

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2 Since steroids are known to influence protein metabolism it is quite possible that alterations in nitrogen balance and steroid ex-

3 Because many conditioning factors affect the specific effe the steroids convincing cause and effect relationships are no evident

Probably the decreased urinary excretion of sodium and the excretion of potassium in the early postburn period are relate increased secretion of aldosterone, such studies, however have no been made in burns Before the discovery of aldosterone it was cult to explain in terms of adrenal function the occurrence of a soc diuresis and decreased potassium excretion at a time when a high put of adrenal steroids could be measured in the urine This i longer paradoxical since the steroids that were measured are unde control of ACTH while aldosterone is not It is therefore, not diff to conceive of dissociation of output of various adrenal horm having different functions and being controlled by different fac The rapid progress being made in the biochemistry and physiolog steroid hormones indicates that the metabolic response to burns soon be explained more clearly in terms of specific functions of vari adrenocortical hormones

Eosinophil count has been used as a measure of adrenal funct The count decreases rapidly during the first 12 hours after a burr is commonly reduced to a zero level in 12 to 24 hours Occasion a patient is seen in whom the eosinophil count decreases only afte hours Without knowing the eosinophil count before thermal inj the surgeon is unable to diagnose adrenocortical insufficiency on basis of a postburn count that appears higher than expected This is important point, since it is extremely difficult as well as dangerou make a diagnosis of adrenal failure in burns. After the first two p burn days the eosinophil count generally increases. Failure of count to increase usually indicates that a stressful complication occurred and this is generally accompanied by a poor progno For unexplained reasons the count often rises to exceptionally h levels during convalescence [23]

Thyroid

Observations by Cope on patients having severe burns reveale striking elevation of the metabolic rate a normal protein bou iodine concentration in the blood and a normal uptake of radioact iodine by the thyroid gland Since the two latter measurements more or less specific tests of thyroid function it must be conclud that thyroid hyperactivity is not responsible for the increased me bolic rate In Cope s studies, the metabolic rate was often plus 30 plus 60 in extensive burns It was roughly proportionate to the sever of the burn and tended to remain elevated until wound healing w

almost complete [4] The factors that may be responsible for the increased metabolic rate include epinephrine discharge due to anxiety and pain fever and intense metabolic activity in the wound The increased metabolic rate is undoubtedly related to the wasting that is so characteristic in severely burned patients

Gonads

Menstruation ceases in women sustaining burns and it does not return until late in convalescence Mild testicular atrophy is quite common in men It is not known whether these changes are mediated by primary depression of the gonadotropic principles of the anterior pituitary by alterations in adrenal function by generalized mal nutrition, or by a combination of these factors

Anterior Pituitary

Although blood assays for ACTH have not been reported in burns, the adrenal changes observed point towards increased ACTH secretion for long periods of time There is no information about growth hormone activity in the plasma, a satisfactory assay for such activity has not been developed It would be extremely interesting to learn whether a patient's extraordinary capacity for protein synthesis during convalescence is mediated via growth hormone Perhaps the synthesis of proteins in amounts that exceed the previously incurred losses—an unusual and outstanding feature of protein metabolism during convalescence—is also related to increased growth hormone activity Assays for urinary gonadotrophins have not been re ported Normal thyrotropic hormone metabolism may be inferred from the normal indices of thyroid function

Parathyroid

Although hypercalciuria and hyperphosphaturia are common, limited data on serum calcium and phosphorus levels indicate that they are normal in most patients The roentgenologic appearance of the skeleton is that of osteoporosis and not of osteitis fibrosa cystica From these and other data it may be inferred that marked alterations of parathyroid function do not occur The hypercalciuria and hyperphosphaturia are best explained by the effects of prolonged immobilization and high intakes of calcium and phosphorus

"Stress Diabetes"

A moderate transient hyperglycemia is a common sequel of burning This phenomenon is of no clinical importance as a rule and it usually disappears in several days

In some patients the blood sugar concentration increases to a very high value (about 1 000 mg. per cent)[8, 16] This marked hyper glycemia may not be associated with ketosis or acidosis. The patients appear very ill because of severe deficits of salt and water The latter is often evidenced by marked hypernatremia, in some instances the serum sodium concentration being above 160 mEq per liter If the condition is recognized promptly energetic therapy with insulin and fluids is effective Unfortunately the correct diagnosis is often delayed. Death results from renal failure manifested by severe oliguria, azotemia and hyperkalemia.

The pathogenesis of this syndrome is not understood All the cases observed thus far have been associated with forced feeding The syndrome is apparently caused by excessive carbohydrate intake in patients whose carbohydrate tolerance is impaired presumably because of increased adrenocortical activity The seriousness of this complication and its constant association with increased carbohydrate intakes are strong arguments against energetic forced feeding regimens in the early postburn period.

VITAMINS

Abnormal vitamin metabolism has not been noted in patients sustaining uncomplicated burns of small extent. The plasma ascorbic acid concentration is low in the case of severe burns When ascorbic acid is given intravenously the urinary excretion of the vitamin does not increase as it does in healthy subjects Data of this type have been interpreted as indicating increased tissue demands and hence the need for the administration of large doses of vitamin supplements The metabolism of thiamine riboflavin and nicotinic acid have been studied similarly It is concluded that these vitamins are needed in greater amounts by burned patients.[15]

No data are available on the other water-soluble or the fat soluble vitamins However from available knowledge concerning calcium and phosphorus metabolism it may be concluded that supplements of vitamin D are contraindicated

NUTRITIONAL THERAPY

Serious nutritional problems are unlikely to arise in patients having burns of relatively small extent and in cases where most of the burn wounds are predominantly partial thickness If nausea and vomiting occur at all, these complications cease within a few days and the patient can then ingest increasing quantities of food Troublesome anorexia is rare A degree of weight loss roughly proportionate to the extent of injury may be expected but this is not clinically im-

portant. Excellent healing is the rule Patients should be encouraged to take a diet of 100 to 125 gm of protein and about 3,500 calories Vitamin supplements should be given

The adequacy of nutritional support may make the difference between survival and death in a patient having severe burns The more severe the injury, the more critical the nutritional therapy becomes Intelligent and effective nutritional support may be administered despite the fact that many facets of the complex metabolic response to burns are not fully understood

Objectives in Nutrition

From time to time, extreme points of view have been expressed about the aims of nutritional therapy Some writers have maintained that a patient s metabolic response to burns is nature's expression of the best way to combat the severe stress of burning. It is claimed that the marked outpouring of nitrogen products reflects the body s effort to make building stones available for wound healing In this sense, the metabolic response as measured by nitrogen balance is a beneficial event and should not be thwarted by therapy In support of this thesis it has been pointed out that excellent healing of wounds occurs at a time when nitrogen balance is negative Poor healing capacity is noted among debilitated patients who fail to respond to burns by increased nitrogen excretion Some writers who oppose this premise maintain that the sole function of any supportive therapy is to keep body composition as normal as possible and avoid all losses by prompt provision of adequate nutrients

It is an undisputed fact that excellent healing occurs in the presence of strongly negative nitrogen balance. However, it is also true that *persistent* negative nitrogen balance results in serious debilitation increased susceptibility to invasive infection, poor granulation tissue, poor graft takes, and delayed healing of donor sites These complications are often responsible for the death of a patient Thus if a patient s metabolic response to burns is disregarded and a nutritional laissez faire attitude is assumed, disastrous results may follow

It is unwise to institute immediate forced feeding programs to offset all nitrogen losses Although it is theoretically possible to achieve nitrogen equilibrium in the early postburn period, there are no indications that this is desirable During the first five to ten postburn days, seriously burned patients often have nausea vomiting, and gastrointestinal atony as manifested by abdominal distention and decreased peristalsis Acute gastric dilatation is not uncommon (Fig. 84) Forced feeding may be followed by unusually severe gastric dilatation. Abdominal distention periodic nausea and vomiting, and

FIG 84 Roentgenogram showing acute gastric dilatation. Note that the stomach extends down to the brim of the pelvis.

gastric dilatation may then persist for several days This prevents the institution of an effective nutritional program and the patient may become severely malnourished While it is true that seriously burned patients may have such difficulties resulting from sepsis in the absence of early forced feeding experiences of this type are sufficiently common that early forced feeding must be considered hazardous An additional warning against its use is furnished by experience with stress diabetes

The essence of a proper nutritional program consists in good timing [17] The patient should receive increasing quantities of nutriments when his gastrointestinal tract is capable of accepting them and when reasonably efficient utilization may be expected Good timing may be achieved provided the patient s general metabolic response is understood, careful clinical observations are made and the need for adjustment to the individual requirements of particular patients is appreciated

The Role of the Wound

Although specific data are lacking, there is little doubt that the burn wound itself initiates and perpetuates metabolic abnormalities In the early phases, the wound and the inevitable infection associated with it probably cause some of the changes in the balance of minerals and hormones In the later phases, the nitrogen losses via the wound exudate may be very great. When a patient s clinical condition is appraised, consideration must be given to both his nutritional status and the condition of the wounds. They are inseparable each contributing substantially to the other Preoccupation with the therapy of one at the expense of the other may lead to disaster

DETAILS OF MANAGEMENT

During the first two days after injury it is best to rely on intravenous feeding altogether because nausea and vomiting are quite common Thereafter, patients should be encouraged but not forced to ingest increasing quantities of food Liquids are usually preferred Such a regimen will assuredly result in substantial tissue losses but this condition is preferable to some of the complications of early forced feeding

The time when a high protein, high-caloric intake becomes mandatory varies greatly In an uncomplicated case, good intakes should be attainable within seven to ten days By this time, ingested protein is utilized efficiently The characteristic nitrogen intake-nitrogen balance relationship is shown for various postburn periods in Figure 85 As time progresses, utilization of ingested nitrogen becomes increasingly efficient This is indicated by decreasing amounts of nitrogen intake required for the attainment of equilibrium.

Anorexia is an almost constant sequela of a severe burn When the patient is judged capable of sufficient intake, persuasive encouragement may not induce him to eat enough food It may then become necessary to resort to tube feeding. This procedure is kinder in the long run than allowing the patient to deteriorate to a state of hopeless debilitation.

Recommended Intake

A daily protein intake of 2 to 3 gm per kilogram is desirable [13] In most adults the daily intake should range between 150 to 220 gm of protein The caloric intake should be 50 to 70 calories per kilogram Routine daily vitamin supplements are recommended as follows ascorbic acid, 1 000 mg. thiamine 50 mg. riboflavin, 50 mg and nicotinamide, 500 mg These amounts are contained in three or four capsules of many proprietary preparations.

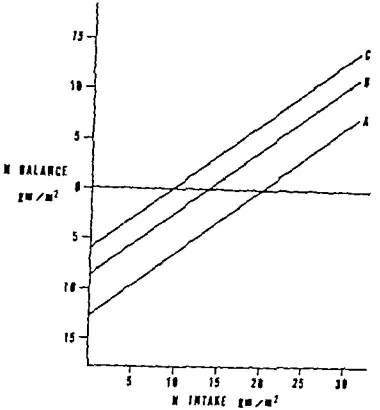

FIG 85 Simplified representation of the characteristic relationship of nitrog intake and nitrogen balance *obtained from unpublished observations of H S. Soo* and E. Pearson. The nitrogen intake required to achieve balance decreases progressive Line A 7 to 17 days Line B 30 to 40 days and Line C 60 to 70 days.

Feeding Methods

Oral feeding is always preferable to intravenous feeding. If th patient is still unable to take food orally after two days intravenou feeding with 10 per cent dextrose solutions and amino acid hydro ysates may be used but the physician must realize that such a metho is totally inadequate However it is better than no feeding at all an it must be used if the oral route is not available Intravenous feedin programs will remain unsatisfactory until intravenous fat emulsion can be administered safely It may be desirable occasionally to supple ment a sub-optimal oral intake by intravenous feeding but the gai thus achieved is rarely worth the discomfort, expense and effort

The routine serving of three standard hospital meals is a totall inadequate diet for severely burned patients. The physician and th dietitian must collaborate in planning a diet containing foods that th patient likes and excluding those he dislikes The physician should in sist on a patient s eating at least part of the basic menu even if high protein liquids or tube feedings are used as supplements The dietitian should supervise the preparation serving of all food She should

calculate not only the calories and grams of protein actually taken by the patient but also the portions he rejects This information should be a part of the patient s chart

Standard menus rarely suffice for the patient s protein and caloric needs, therefore various supplements are used The supplementary feeding should be a palatable liquid given between meals Formula A is a sample of an acceptable high protein mixture (Table 4) Provi

Table 4 Supplementary Feeding Formulae

CONTAINED IN EACH 1,000 cc.	FORMULA A (Provimalt*)	FORMULA B (skim milk and dextri-maltose)
Calories	1 184	1 670
Protein	87 gm	56 gm
Fat	36 gm.	48 gm.
Carbohydrate	116 gm.	263 gm.

Formula A

4 tablespoons, Provimalt* powder 1 tablespoon, chocolate syrup *8 ounces of whole milk*	Prepare in a blendor in order to secure a *smoother mixture.*

Formula B

whole eggs, 100 gm. dry skim milk, 40 gm. dry whole milk 270 gm. Dextri-maltose #1 289 gm. chocolate syrup 137 gm. water to make 1,800 cc.	Place dry ingredients and whole eggs *in a blendor jar on top of small* amount of water Blend until lumps disappear then make up to volume

* Provimalt, a palatable *and high-protein powder is manufactured by Humanic* Brands, Inc., Summit, New Jersey

malt,† a high protein powder, is one of several preparations com mercially available Its advantage over many other preparations is its palatability Patients can be encouraged to accept almost any supplementary feeding for one or two weeks, but the burned patient must continue a high intake for several weeks or even months and palatability therefore becomes a very important factor Formula B is an inexpensive supplementary formula to be used as between meal feed ings or as a tube feeding (Table 4) This formula may be prepared easily in any diet kitchen, and it can be modified as necessary by changing the proportions of the ingredients Other supplementary formulas are to be found in standard dietetic reference books Supplementary feedings may be served in 200 cc. amounts between meals and especially in the evening hours and during the night The custom

† The use of this product by the authors cannot be construed to mean its endorsement by the Medical Corps, United States Army

in hospitals of not feeding patients who need supplemental food between the hours from 5 o'clock in the evening until 7 o'clock in the morning is unjustifiable. It is advisable to awaken a burned patient during the night in order to increase his dietary intake.

TUBE FEEDINGS. It is difficult to give positive indications for the institution of tube feedings. An indwelling nasogastric tube is uncomfortable, and its use may be followed by complications such as gastric dilatation, aspiration and respiratory infection. Extreme care must be exercised in using tube feedings in burned children and seriously ill patients. In almost all extensive burns, however, tube feedings are necessary, and they may be lifesaving. Tube feedings should be instituted at any time after the first seven or ten days when a burned patient fails to increase the intake of food up to the recommended nutritional requirement.

Formula B may be used as a tube feeding formula as well as an oral supplement (see Table 4). A homogenized formula may be prepared by blending the contents of a high-protein, low residue, ground meat diet with 500 cc. of whole milk. Although this is somewhat difficult to prepare, many patients tolerate this formula better than Formula B. The caloric content of the homogenized food formula may be increased by the addition of a fat emulsion.* Sometimes it is advantageous to order two trays for the patient for each meal, the food from one tray to be eaten, food from the other tray to be homogenized and given between meals.

Tube feedings must be started gradually. Before the feeding is initiated and during the first few hours thereafter, the abdomen should be examined for the presence of bowel sounds to make sure that the gastrointestinal tract is not atonic. The commonest error in tube feeding consists in beginning with an excessive volume. It is best to give a small amount per day at first (500 cc.), then increase the volume gradually over a four- to five-day period until the desired intake is achieved. Most patients can tolerate 2,000 to 2,400 cc. per day if the formula is not too concentrated. A continuous drip of 400 to 500 cc. may be given at various intervals, or 50 to 200 cc. may be injected through the tube every two hours. If a slow drip is given over a 24-hour period, the formula may spoil on standing for a long time at room temperature, especially in the summer.

Diarrhea is the most frequent complication of tube feeding. It may be caused by too rapid an increase in the volume given, or by a mixture that is not suitable for the patient. When diarrhea occurs, the volume of food is decreased immediately. If it persists, the carbo-

* Lipomul is an oral fat emulsion, prepared by the Upjohn Company, Kalamazoo, Michigan. Each 100 cc. provides 10 gm. of carbohydrate, 40 gm. of fat, and 400 calories.

hydrate content is reduced Some formulae are poorly tolerated because of an excessive fat content Simple experimentation with these variables nearly always results in an acceptable program It should be reiterated that tube feeding does not contraindicate the concomitant ingestion of at least small amounts of a basic menu Eating is good for morale, and patients should not be allowed to get out of the habit of eating.

NONDIETARY THERAPY

Hormones

Androgens have anabolic activity and because of this they have been used in burn therapy Testosterone proprionate is the androgen most widely used. Although testosterone has a distinct nitrogen sparing effect, this is not impressive in a quantitative sense Three or four weeks after thermal injury, administering increased amounts of protein is by far a more efficient method of improving nitrogen balance than administering testosterone. In many instances the anabolic effects of testosterone appear to diminish after several weeks Retention of sodium and water is a hazard with testosterone therapy The over-all role of testosterone in the treatment of burns is difficult to assess There appears to be no strong contraindications to its use in men On the other hand, testosterone does not have beneficial effects that are not more easily and efficiently achieved by simpler means

ACTH AND CORTISONE. Early claims about the miraculous effects of ACTH in the initial postburn period were soon disproved in a most decisive manner Neither ACTH nor cortisone affects the accumulation of burn edema

A more difficult question to deal with concerns the occurrence of actual or relative adrenocortical insufficiency in the first two postburn weeks Acute adrenocortical insufficiency is characterized by fever hypotension, signs of extracellular fluid volume deficiency vomiting hyponatremia and increased urine sodium excretion All of these symptoms may be observed in patients sustaining severe burns when adrenal function is normal

The clinical syndrome of adrenal insufficiency is closely mimicked by overwhelming sepsis The difficulties in diagnosis are well illustrated in the following case report.

Patient C W A 65-year-old Negro male received full-thickness burns of 25 per cent and partial-thickness burns of 15 per cent of the body surface when a mixture of paint thinner exploded

The clinical course in the first two days was very satisfactory as judged by clinical signs, urine volume, and laboratory data. On the fourth day his temperature increased from 99° F to 102.6 F he became disoriented, and his blood pressure decreased to

60/40. Pulmonary edema developed, but responded to rapid digitalization. Gastric dilatation was noted and treated by suction. Hypotension persisted despite the infusion of blood and vasopressor drugs. The plasma sodium was 130 the urinary sodium 136, and the urinary potassium 35 mEq/L.

The diagnosis of acute adrenocortical insufficiency was suggested by the acute onset of fever hypotension, gastric dilatation, and disorientation mild hyponatremia, and increased urinary sodium concentration. Cortisone was given orally and intramuscularly but the patient's course became progressively worse and he died on the sixth day

Antibiotic therapy consisted only of penicillin. Results of blood culture taken on the fourth day were not known until after the patient's death It was positive for beta hemolytic streptococcus, Aerobacter Klebsiella and paracolon bacillus. At autopsy there was an acute endocarditis of the aortic valve. The adrenals were enlarged but otherwise normal.

This patient was treated before the importance of the septicemia problem in burns was recognized The differential diagnosis is obviously difficult The most important diagnostic point is that septicemia is quite common and adrenal insufficiency is rare In fact the recent literature contains only two cases of well-documented adrenal insufficiency following burns. One patient was treated by Levenson and his case was associated with amyloidosis that occurred after prolonged sepsis [14] Mandelstam treated a patient in whom there was frank adrenal insufficiency with a good response to steroid therapy [16]

Small adrenal hemorrhages are often seen at autopsy but these hemorrhages also occur in other organs, and functional studies during the life of such patients generally reveal evidence of marked adrenal hyperfunction not hypofunction

Septicemia is being recognized with increasing frequency in patients having extensive burns its incidence depends to a large extent on early recognition of this complication When confronted with a case such as that of Patient C W, the physician should institute treatment for septicemia and search for evidence of adrenocortical insufficiency Measurement of the urinary 17 hydroxysteroids the plasma sodium concentration the urinary sodium excretion and the eosinophil count are of some diagnostic value

It has been claimed that although the adrenals may function actively they fail to secrete hormones in sufficient quantities to meet the unusually large requirements imposed by the stress of a burn Some data in support of this claim, indicate that cortisone treated animals have a longer survival rate than control animals. Experiments of this type are not reproducible however and no established clinical data parallel these experimental studies Although controlled observations have not been made on burned patients sufficient data have been reported to indicate that cortisone has no significant protective action in man Cortisone has also been recommended to lessen the severity

of toxemia, a vague term that refers to the stormy clinical course in the early postburn period of severely burned patients Toxemia is probably a manifestation of septicemia Combined steroid and anti biotic therapy has been recommended for the treatment of infections with unusually severe clinical manifestations Experience indicates that steroids do not have a favorable effect on the course of septicemia resulting from burns Steroids in large doses of course, can depress some of the defenses against infection and they are potentially dangerous for this reason (see Chapter 7)

ACTH and cortisone have been recommended for patients who are debilitated because of the effects of the burn wound It is claimed that the hormones are indicated because they improve appetite and induce euphoria This use of potent hormones appears to be irrational and is therefore contraindicated Clinical data fail to indicate that these patients have adrenal insufficiency On the contrary all available information points toward active adrenal function.* The influence of ACTH and cortisone on protein metabolism is extraordinarily com plex. It is under investigation in several laboratories These hormones actually increase the urinary nitrogen losses when administered in large doses The use of ACTH or cortisone in the treatment of debilitated patients is as faulty in theory as it is ineffective in practice

Blood

Transfusions are essential for successful therapy They are given for the correction of anemia and not for nutritive purposes The im pairment of hematopoiesis is of such a nature that all specific agents, such as vitamin B_{12}, folic acid and iron, are ineffective Blood lost during operations must be replaced as it is being lost This point must be stressed because of the common tendency to underestimate opera tive blood loss Hematocrit determinations serve as useful guides for transfusion requirements, they should be made at least twice weekly as well as preoperatively Severely burned patients having a hematocrit of less than 40 tend to have a low blood volume They have hypotension during induction of anesthesia and they have poor tolerance for operative trauma Adequate preoperative transfusions usually prevent these difficulties A good empirical rule is to give transfusions in sufficient amounts to maintain the hematocrit at 45 or above

Psychiatric Support

Emotional problems are discussed in some detail in Chapter 10 They are mentioned here because a good relationship between doctor

* Undoubtedly some confusion exists because hypofunction of the adrenal cortex has been demonstrated in starvation not associated with burns.

and patient and simple psychotherapy may appreciably influence the success of the nutritional program

THE DEBILITATED PATIENT

There are few entities in the practice of medicine and surgery that are as difficult to treat as a debilitated burned patient. He has large wounds that are massively infected he has lost 20 to 30 pounds of weight since injury, he cries frequently and complains bitterly of all discomforts, and he refuses to eat more than trivial amounts of food He is often described as the patient who was referred in a neglected condition from the elsewhere' hospital. Patients of this type may also be seen in burn centers where treatment has been given by experienced personnel however treatment has not been successful during some phase of the patient's course. Deterioration may begin insidiously and then it progresses with amazing rapidity In the great majority of instances a careful review of the patient s course will indicate that errors in judgment were committed It is unfortunate that severe debilitation is all too frequently caused by gross blunders or inexcusable neglect

Unavoidable debilitation is likely to occur only in patients who have extensive full thickness injury If the early postburn course is complicated by septicemia and paralytic ileus intravenous feeding may be the only means of nutrition for two or three weeks. Under these circumstances, tremendous tissue losses occur Graft takes are poor in a severely depleted patient and donor sites are likely to become converted to full thickness skin loss

Serious problems may be created by poor timing of grafting procedures The following sequence is not uncommon A patient with a 20 per cent full thickness burn is not grafted for six to eight weeks. He eats poorly weight losses are appreciable and wound suppuration is profuse An extensive grafting procedure is carried out in sheer desperation The grafts do not take and the donor sites are converted to full thickness skin loss The patient s condition is critical A burn that once was of relatively small extent has now become a major problem. In every instance when wound closure has been delayed an overwhelming metabolic problem arises For this reason it must be emphasized over and over again that judicious wound management and metabolic therapy are inseparably interwoven

If a patient is suffering from wound and nutritional decompensation the following regimen has proved valuable

1 *Homografting* (see Chapter 5) This achieves temporary wound closure in turn decreasing nitrogen losses through the wound as well as decreasing the extent of wound suppuration This procedure allows

for time during which tissue stores may be partially repleted by forced feeding. Autografts should not be used because of the dangers of conversion of donor sites to full thickness skin loss

2. *Transfusions* In critical cases, the adequacy of transfusions must be checked not only by the hematocrit but also by blood volume determinations

3 *Forced Feeding*

4 *Psychotherapy* This is a most important factor in the treatment of a debilitated patient.

5 *Testosterone* Its usefulness is doubtful and probably of minimal quantitative importance

Intensive therapy often produces gratifying results in a short time A patient s condition may be improved within two weeks to the point where autografts may be used The limiting factor in the progress towards permanent wound closure then becomes the availability of donor sites

CLINICAL LABORATORY AIDS

Hematocrit

Its value has been stressed Hemoglobin determination may provide additional information

Leukocyte Count

A marked leukemoid reaction with leukocyte counts of 20,000 to 40 000 is characteristic during the first postburn day Then the count becomes normal quite rapidly Throughout the remaining clinical course, leukocytosis with a left shift in the differential count occurs in a degree that parallels the severity of wound infection Leukopenia may be an early indication of septicemia

Urinalysis

During the first week, a urinalysis is performed daily and thereafter at weekly intervals. A transient, mild glycosuria is expected, however if glycosuria is persistent or massive, it may indicate diabetes The urine sediment should be checked carefully for evidence of persistence of postcatheterization cystitis

Plasma Proteins

Routine determinations are unnecessary A moderate hypoalbuminemia is to be expected This is not an indication for intravenous administration of albumin however as it is expensive and produces only a transient increase in the serum albumin An equivalent nutritional effect may be obtained more cheaply by oral feeding.

Body Weight

Besides the hematocrit the weight of the patient is the most important observation to be made Ward scales may be fitted with adjustments to make possible the weighing of patients on stretchers or Stryker frames Unless there are strong contraindications, patients *should be weighed daily during the first seven to ten days* Thereafter the weight should be determined at least twice weekly

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CHAPTER 9

Special Types of Burns

ELECTRICAL BURNS

THE TWO IMPORTANT factors in electrical burns are the systemic effects of the electric current and the effect of the local burn wound

Systemic Effects of Electric Current

Because of a number of variables the exact amount of electric current that the body can withstand has not been ascertained Direct *electric current is less dangerous than alternating current. Direct cur* rent of 200 to 250 milliamperes may be tolerated without serious injury but 70 to 80 milliamperes of alternating current may produce death if the current passes through the heart

The degree of injury to the body is more or less proportionate to several factors—the amperage the voltage and the resistance of that part of the body with which the current comes in contact The high tension currents used by municipal lighting plants and railway systems are very dangerous because their voltage ranges from 220 to 1 000 volts with a correspondingly high amperage Hyslop and Miller reported that approximately 10 deaths occurred over a period of 30 years from 110-volt household circuits in the state of Wisconsin [2]

An alternating current of very low amperage is not harmful even when the voltage is fairly high Currents of high amperage are not necessarily dangerous to life if the voltage is very low although a burn may result if the contact is good Resistance both at the site of contact and within the body is important as are the size and type of electrode encountered The skin of all parts of the body is somewhat resistant to electricity but the soles of the feet and palms of the hand are considerably more resistant than other areas.

The pathway of the current is another variable which has an important bearing on the effects of the current The heart is the danger

area Moderate current passing from one foot to the other is seldom fatal whereas a small current passing through the chest may prove fatal Currents from the left hand to the right hand or to the feet are more likely to be fatal

Contact on the palmar aspect of the hand is more dangerous than on the dorsal surface because the former causes flexion of the fingers with consequent grasping of the contact while the latter causes sudden extension of the fingers so that the contact is usually knocked away The resistance to electric current in tissues varies in the order given from greatest to least bone, fat, tendon, skin muscle blood, nerve The blood vessels are extremely good conductors of current, and this phenomenon accounts for the frequency of vascular lesions, such as thrombi

If resistance of the skin is low at the time it interrupts the electric current, the current passes readily into the body, causing propor tionately severe systemic disturbances However, if the skin maintains its resistance during contact, the current may be retarded and the systemic damage is less Other things being equal the greater the skin resistance, the more severe the local burn, and similarly the less the resistance, the greater the systemic effect of the current

Brown has stated that death due to an electric current generally results from ventricular fibrillation failure of the respiratory center, or sometimes from a combination of the two [1] Pack believed that the best conclusions to be drawn from the voluminous literature on causes of death by electricity are that very high tension currents may cause a fatal electric shock in which cardiac asystole and cessation of respiration occur simultaneously Death from low intensity current is due to ventricular fibrillation, particularly when the heart is in the course of the flow of the current. With higher voltage currents however, respiratory failure occurs first and may be due either to direct depression of the respiratory center or to hemorrhage in the region of the fourth ventricle [3]

When death occurs from ventricular fibrillation, breathing con tinues and becomes quite rapid, but after about two minutes respira tion fails. The victim is pale but not cyanotic When the respiratory center fails however breathing stops and the victim becomes un conscious, but the heart action continues The blood pressure falls rapidly and the victim quickly becomes cold and cyanotic Death ensues within ten minutes unless artificial respiration is instituted

Treatment of Electrical Shock

The victim should be freed from the electric current as quickly as possible. The rescuer must make sure that the current is off before

touching the victim to avoid being injured by the current. The current may be switched off or the wires may be cut with a long, wooden handled axe or properly insulated pliers Artificial respiration must be started immediately if the victim is not breathing. Because death due to an electrical shock is usually not immediate, artificial respiration must always be tried and the victim should be moved to a hospital at the earliest opportunity If a diagnosis of ventricular fibrillation can be made and facilities are available, cardiac massage should be instituted

Local Electrical Burn Lesions

The severity of an electrical burn is generally underestimated if appraised soon after injury Deep destruction from the intense heat, as the result of contact with an electric current, and thrombus formation are the chief differentiating factors from other burns The heat which produces an electrical burn is far more intense but of less duration than the heat which produces any other type of burn Burns caused by an electric current are characterized by an added degree of thrombosis that extends into the surrounding area

An initial inspection shows surface damage, however deeper pathologic alterations and thrombosis do not become evident until 24 to 36 hours later when the skin around the eschar becomes hyperemic and inflamed. The eschar often has a charred appearance, and it may become so edematous that it resembles moist gangrene Blister formation is not common The development of pathologic changes in the tissues beneath the eschar makes the resultant skin damage considerably greater than is usually anticipated One of the most dangerous complications of electrical burns is secondary hemorrhage. This results from the necrosis of the vascular walls following subjection to extreme heat

Local Treatment

The initial therapy for electrical burns is essentially the same as that for other deep burns Antibiotics, tetanus toxoid or antitoxin, and appropriate replacement therapy are given. The area must be cleansed Treatment by exposure is preferable in order that the wound may be observed frequently

Most surgeons agree that excision of electrical burns is preferable but there has been considerable debate about the time of excision Hyslop and Miller emphasized that the burned area should be excised within a few hours after the accident They felt that waiting longer than 12 hours would make surgical excision considerably more

FIG. 86. *A* Electrical burn of anterior right shoulder and neck on the fifth postburn day A definite central zone—dark and necrotic—is surrounded by in inflammatory area.

B The 16th postburn day Areas of necrosis have increased in size. Inflammation and edema have subsided The extent of full-thickness skin loss is clearly delineated. The injured areas were excised, and a dressing was applied.

C. The 23rd postburn day Excised areas are ready for grafting. The grafts took well.

difficult since the lines of demarcation between devitalized and healthy tissue are then beginning to be lost.[2]

However it seems advisable to allow the burned area to demarcate completely before attempting excision. If excision is carried out within the first 24 hours after burning the amount of tissue removed is often quite inadequate Additional necrotic areas will appear a few days later When excision is carried out between the third and the sixth postburn day the dead tissue can be appraised more accurately After excision has been performed, a dressing is applied and the wound is grafted from three to five days later (Fig. 86) This delay in closure permits a second look to make sure that all the devitalized tissue has been removed before the skin graft is applied

CHEMICAL BURNS

Most chemical burns occur in laboratories and in industrial plants In warfare chemical burns are caused by phosphorus magnesium, and vesicant gases Acute injury to the skin resulting from chemical agents is similar to that caused by heat, in fact the injurious effects of a chemical are sometimes due in part to the development of heat The skin is protected against caustic burns by the keratinized layer

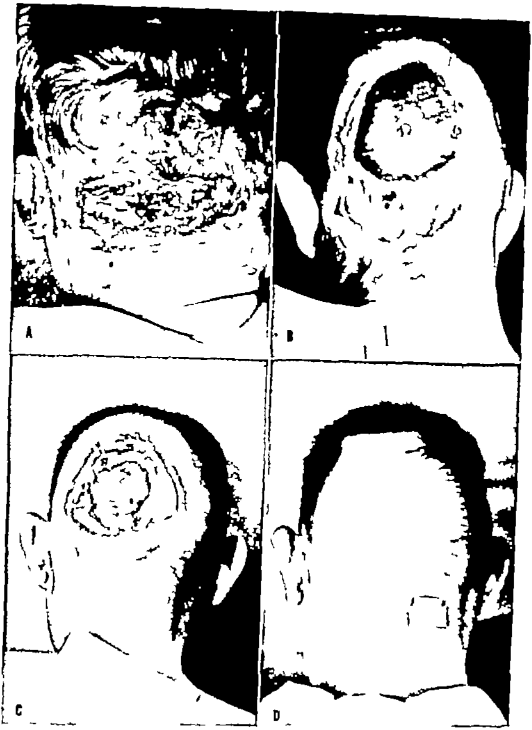


FIG 87 *A* The 4th postburn day Severe electrical burn of the posterior aspect of the scalp The full extent of damage is not apparent.

B The 46th postburn day The damaged portion of the skull has been removed. The dura is covered by a perforated metal plate. Granulations from the dura grew through the metal plate and served as a bed for grafting.

C The 100th postburn day The skin graft over the plate shows a good take and epithelium is growing in from the edges. The outer table of the denuded skull was later perforated with multiple drill holes. Granulations then covered this area, and further split-thickness grafts were applied.

D Appearance at the time of discharge.

and by surface oils. Once these barriers are penetrated by a strong caustic or by prolonged contact with a more dilute solution, burning and tissue destruction are inevitable The cauterization continues until the injuring agent is chemically united with tissue elements, neutralized, or removed by washing.

The lesions produced by a chemical agent present a pathologic picture showing different degrees of destruction from a central zone of necrosis to a peripheral hyperemic area

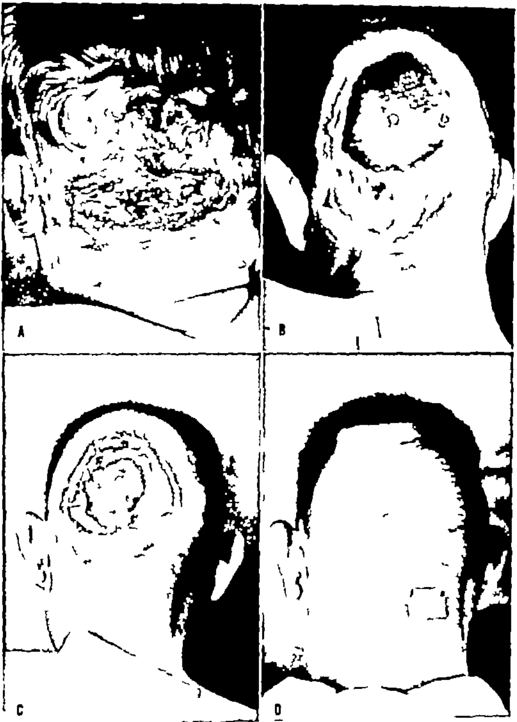
Alkali Burns

Burns from caustic alkalis are usually caused by sodium hydroxide (caustic soda), potassium hydroxide (caustic potash), or lime (calcium oxide) Alkalis exert their pathologic effect in three ways they saponify the fat, they extract considerable water from the cells because of their hydroscopic nature, and they dissolve and unite with the proteins of the tissues to form alkaline proteinates The alkalis are capable of deep penetration and, unlike strong acids, can cause severe pain Terry has stated that the coagulum of necrotic tissue caused by caustic soda may hold some uncombined caustic soda which diffuses into the deeper tissues for several days and thus increases the depth of necrosis [5]

The initial treatment for burns caused by strong alkaline solutions is washing with water The part must not be soaked in water but large quantities of water must be poured over the area in order that the fluid may carry away any heat of dilution to prevent further damage When lime unites with water calcium hydroxide is formed and considerable heat is released. In lime burns the dry lime should be brushed away before washing to minimize this production of heat

In some instances, attempts may be made to neutralize the alkali, but this is not the practice generally recommended The most readily available material for removing a chemical agent is water and it is extremely important to remove the chemical agent as rapidly as possible. Therefore, washing with large quantities of water is the preferred treatment It must be remembered that a neutralizing agent may have a more harmful effect than the burning agent In the haste attending an emergency occasionally a strong, acid solution is selected in an attempt at neutralization, and such a solution causes more damage than the original chemical

After extensive experience in England Terry found that a 5 per cent solution of ammonium chloride is very effective for caustic soda burns If such a solution is used for irrigation within the first five minutes, the damage caused by caustic soda is considerably lessened This concentration of ammonium chloride is perfectly harmless to



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Burns from caustic alkalis are usually caused by sodium hydroxide (caustic soda), potassium hydroxide (caustic potash), or lime (calcium oxide) Alkalis exert their pathologic effect in three ways they saponify the fat, they extract considerable water from the cells because of their hydroscopic nature, and they dissolve and unite with the proteins of the tissues to form alkaline proteinates The alkalis are capable of deep penetration and, unlike strong acids, can cause severe pain Terry has stated that the coagulum of necrotic tissue caused by caustic soda may hold some uncombined caustic soda which diffuses into the deeper tissues for several days and thus increases the depth of necrosis.[5]

The initial treatment for burns caused by strong alkaline solutions is washing with water The part must not be soaked in water but large quantities of water must be poured over the area in order that the fluid may carry away any heat of dilution to prevent further damage When lime unites with water calcium hydroxide is formed and considerable heat is released In lime burns, the dry lime should be brushed away before washing to minimize this production of heat

In some instances attempts may be made to neutralize the alkali, but this is not the practice generally recommended The most readily available material for removing a chemical agent is water, and it is extremely important to remove the chemical agent as rapidly as possible Therefore, washing with large quantities of water is the preferred treatment It must be remembered that a neutralizing agent may have a more harmful effect than the burning agent In the haste attending an emergency occasionally a strong, acid solution is selected in an attempt at neutralization and such a solution causes more damage than the original chemical

After extensive experience in England Terry found that a 5 per cent solution of ammonium chloride is very effective for caustic soda burns. If such a solution is used for irrigation within the first five minutes, the damage caused by caustic soda is considerably lessened This concentration of ammonium chloride is perfectly harmless to

tissues and does not injure the eyes After thorough irrigation with ammonium chloride, the wound must be rinsed again with copious amounts of water [5]

After initial care is given to burns caused by a strong alkali the local areas are treated the same as any other burn

Acid Burns

The various concentrated acids particularly the mineral acids, have a somewhat similar action on the tissues They withdraw water from the cells and they precipitate proteins to form acid proteinates. *Sulfuric acid* converts the corroded tissue into a greenish-black or dark brown slough *Nitric acid* causes a yellow color which becomes a yellowish brown *Hydrochloric acid* is a much less severe caustic than nitric or sulfuric acid and stains the skin yellowish brown *Trichloroacetic acid* is the most corrosive of all organic acids It forms a white soft slough *Phenol*, a destructive and poisonous organic acid causes an initial white slough that turns to a greenish black or copper color

Acid burns should be treated by diluting or removing the acid as rapidly as possible usually by irrigation with large quantities of water After removing the maximal amount of acid by washing the remainder may be neutralized by a weak solution of baking soda The soda solution is prepared by dissolving a heaping teaspoonful of baking soda in a pint of water The eyes may be irrigated with this solution without fear of irritation Since phenol is not very soluble in water phenol burns not involving the eyes should be washed with ethyl alcohol as it readily neutralizes the acid, then they should be irrigated with large quantities of water

After initial emergency care is given the local treatment of acid burns is the same as that for other thermal injuries (Fig. 88)

Phosphorus Burns

In 1943 Rabinowitch reviewed the subject of phosphorus burns, and most of the current practice in their management is based upon his concepts Phosphorus gives off phosphoric acid which then causes injury to the skin [4] As long as particles of phosphorus are in contact with the air they continue to exert a damaging effect In the initial management of a phosphorus burn large quantities of water may be used to wash the surface thereby diluting any of the phosphoric acid that has formed A moist dressing must be applied to protect the injured surface from the air in order to prevent further action of the particles of phosphorus. The patient should be taken to a physician for definitive treatment

It is imperative for the particles of phosphorus to be removed as

Fig 88. *A* The 14th postburn day Sulfuric acid burn of the face. Although excision of eschars on the face is rarely indicated, it was required in this instance because of the tight adherence of the tough eschar

B. Appearance immediately after excision on the 14th postburn day The area is clean and ready for application of a dressing.

C The 19th postburn day Thick split-thickness grafts taken with a Padgett dermatome are sutured in place.

D The graft is completely healed but further plastic procedures were necessary in order to correct the contractures around the eye and the lips.

quickly and completely as possible Phosphorus particles are difficult to identify Application of a 1 per cent solution of copper sulfate converts the phosphorus to copper phosphide a black compound that is easily recognized and can then be removed Copper sulfate does not destroy or neutralize the phosphorus One application of copper sulfate is sufficient, and more than one may be toxic

Oils and greases must not be applied because any phosphorus that has not been removed will dissolve in oil and may penetrate into deeper structures After removal of all visible phosphorus and copper phosphide, the affected areas should be soaked or covered for one or two hours with wet dressings of a soda bicarbonate solution (a heaping teaspoonful of baking soda in a pint of water) The burn should then be re-examined to make sure that all the phosphorus has been removed before a dry dressing is applied If there is any doubt about a residue of phosphorus remaining on the skin, soda bicarbonate soaks should be continued for 24 hours Occlusive dressings are preferred to the exposure method for definitive local care of phosphorus burns

Magnesium Burns

Burns from ignited magnesium are relatively uncommon Usually they occur among workers in munition factories or among persons subjected to incendiary bombing Magnesium burns produce ulcers which are small at first but gradually enlarge to form extensive lesions Wilson and Egeberg have pointed out that the deeper part of the ulcer is usually quite irregular They believe that at first the ignited magnesium is only on the skin and then penetrates irregularly into the deeper tissue By scraping the outer layers of the skin under Novocain anesthesia soon after injury most of the magnesium may be removed [6] Magnesium may be a rapid or slow burning ember depending upon the size of the particles involved If the slow burning embers penetrate deeper than the outer layers of the skin they must be excised completely and the resultant wound must be closed by means of delayed primary suture or by skin grafting

Vesicant Gases

Mustard gas and Lewisite are war gases that cause severe blister formation In civilian practice burns may result from careless handling of nitrogen mustard In general the clinical appearance of burns caused by vesicants is indistinguishable from second-degree burns The blisters are surrounded by large areas of erythema (Fig 89) Delayed blister formation is common Early local care consists of washing with copious amounts of water Definitive local care is the same as that for other second-degree burns

FIG 89 Mustard gas burn at 27 hours after injury The large blebs surrounded by a wide zone of erythema are typical.

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CHAPTER 10

Practical Details in Burn Therapy

SEVERAL IMPORTANT aspects of burn care were intentionally omitted in the previous chapters Therefore this chapter is concerned with certain practical details in burn therapy including anesthesia for burned patients emotional factors in the care of burned patients, and nursing care of burned patients.

ANESTHESIA FOR BURNED PATIENTS

In no other clinical problem is the team approach between the anesthesiologist and the surgeon as important as in the treatment of a burned patient The severe physiologic and metabolic derangements that occur following thermal injury make such a patient a poor anesthetic and a poor operative risk Repeated anesthetics are necessary for the multiple changes of dressings and grafting procedures required to cover the burn wound

The surgeon should keep the anesthesiologist informed of the general condition of the patient and discuss with him the planning of important operative procedures. After scheduling a dressing change the surgeon often finds that the wound should be excised or grafted In such instances the anesthesiologist can be prepared for the more *prolonged operation if the possible operative procedures are discussed* in advance

It is advantageous for the anesthesiologist to come to the ward frequently to see the patient. This permits him to keep in close touch with the general condition of the patient and at the same time to establish rapport with the patient *It is important for a burned patient* to have real confidence in the anesthesiologist because of the complete *cooperation required during* dressing changes under analgesia A burned patient is understandably afraid of repeated anesthetics and

dressing changes A friendly relationship between the anesthesiologist and the patient promotes a smoother convalescence

In spite of modern methods, anesthesia adds further stress and repeated administration of anesthetics further exhausts the body s already depleted reserves [3] Anesthesia must be avoided whenever possible Attempts should be made to carry out all minor dressing changes under analgesia However, some major dressing changes require anesthesia Some patients are more cooperative than others and require less analgesia. Usually children tolerate dressing changes without an anesthetic agent better than adults.[11]

Analgesia for Dressing Changes

Initial cleansing of an extensive acute burn wound can usually be performed under intravenous morphine sedation Further analgesia or anesthesia should not be necessary

The aim in analgesia at the time of a dressing change is to keep a patient as comfortable as possible but, at the same time, to produce the least amount of narcosis A patient should be awake, capable of cooperating, and able to cough It is usually necessary to withhold breakfast however, with light analgesia, a patient is able to eat soon after the procedure When anesthesia is used repeatedly for dressing changes difficulty is encountered in maintaining a patient in a good state of nutrition because oral feeding must be withheld for long periods.

It is preferable to prepare a patient for analgesia with intravenous morphine A dose of 8 mg. (1 mg of morphine per cc. in normal saline) is given slowly by vein for sedation and repeated later if necessary A dose large enough to achieve narcosis is not desirable Atropine or preferably scopolamine (because of its sedative action) is given concomitantly The surgeon must carry out the dressing change as gently as possible Nitrous oxide and oxygen are administered as necessary in a mixture of 75 per cent of nitrous oxide or less. Occasionally a slight amount of ether may be added but it should be avoided whenever possible.

Although trichloroethylene has been recommended for analgesia in burned patients it seems effective only when given in large doses [9] Then its several side effects become evident and it is really deleterious to a burned patient

Anesthesia for Excision and Grafting Procedures

Morphine and scopolamine are given for preoperative preparation Morphine is preferred to Demerol because a comparable dose of morphine achieves a greater sedative action with less depression The

sedative effects of 10 mg. of morphine sulfate are about equivalent to 125 mg. of Demerol In addition Demerol is a vasodilator and may further expand the already dilated vascular system of the burned patient

Cyclopropane is the anesthetic of choice for major operative procedures on burned patients It is preferable to ether because it acts *more rapidly and is less toxic to the myocardium.* It does not possess the adrenergic qualities of ether such as production of tachycardia and depletion of liver glycogen Prolonged ether anesthesia produces *metabolic acidosis. Once a patient is under control with cyclopropane* the depth of anesthesia may be changed more easily and more safely than with ether This is particularly advantageous in grafting procedures *when deeper anesthesia is required for cutting the skin and very* light anesthesia is satisfactory for application of skin The chance of secondary depression postoperatively is less after the use of cyclopropane

Irrespective of the type of inhalation agent used it is extremely important that a burned patient be given a high concentration of oxygen throughout the operative procedure.

Pentothal sodium should be used only in sedative amounts The prolonged use of Pentothal in amounts adequate to perform major operative procedures is not recommended because it will result in peripheral cardiovascular central midbrain and medullary depression

It is important to warn the anesthesiologist that the patient must not move towards the end of the operative procedure while the dressing is being applied One of the most important phases of a grafting procedure is the application of the dressing because it holds the graft in place If the patient moves *while the dressing is being applied* slipping or wrinkling of the grafts may cause a poor take In this respect the rapid action of cyclopropane is particularly advantageous *Its use permits the anesthesiologist to keep the patient asleep until* the end of the operative procedure then as soon as cyclopropane is discontinued the patient awakens quickly

A tracheotomy is required before anesthesia in patients who have deep burns about the face Under such circumstances tracheotomy is positively indicated because of the multiple anesthetic procedures that must be carried out (see Chapter 6)

Supportive Care During Anesthesia

One of the most important responsibilities of the anesthesiologist is general supportive care during the operation *Burned patients do*

not compensate for losses from the vascular system as well as general surgical patients The patient frequently has a high fever and a rapid pulse Hypotension during anesthesia is quite common unless careful attention is paid to replacement therapy

The patient s blood volume must be adequate preoperatively An intravenous lifeline must be assured before major anesthesia is undertaken Usually the number of available veins in a burned patient is limited and extreme care must be taken of veins to provide a well functioning intravenous portal all the time during anesthesia If peripheral veins are not available, a femoral cannula may be used

In major grafting procedures, transfusion of blood should be initiated as soon as the operation is started The major blood loss in grafting procedures occurs during the first half hour or hour Blood is lost from the donor sites as the skin graft is taken It is also lost from the recipient site because of the bleeding of granulation tissue during preparation for grafting All too often the anesthesiologist waits until the operation is well under way and the blood pressure is falling before giving any replacement therapy It is imperative that the anesthesiologist observe the operative procedure carefully in order to replace blood loss as it occurs Once the patient has become hypotensive, very large amounts of blood may be required to restore him to a normotensive state

The burned patient who is under anesthesia for a prolonged period does not respond well to changes in position and to changes in temperature Body manipulations should be avoided as much as possible It is common to see two or three teams of surgeons working on various extremities. As these extremities are moved into different positions, persistent hypotension may occur Whenever possible it is advisable to plan the grafting procedure in such a manner that the patient will not have to be turned during the operation

Patients do not tolerate the marked change in temperature between a warm ward and an extremely cold, air-conditioned operating room particularly when dressings are removed from large wound surfaces. Care should be taken to prevent the operating room from being unusually cold

Postanesthetic Care

It is not uncommon for a burned patient to become quite cyanotic as soon as he is moved from the operating room This phenomenon may follow prolonged inhalation anesthesia and frequently it is due to diffusion hypoxia [5] It can be prevented if the patient s condition is stabilized in the operating room by using oxygen for several minutes

after discontinuing the anesthetic It is usually advisable to administer oxygen by mask for about ten minutes then the patient should breathe room air for a short period of time before he is moved from the operating room

Hypotension after anesthesia may also cause cyanosis it may be due to a low circulating blood volume with peripheral stasis or to postanesthetic hypoxia Hypoxia after prolonged narcosis may cause vasodilatation and in turn, hypotension It is desirable to administer oxygen by nasal catheter on the ward for the first few hours after anesthesia to all burned patients who have had a major operative procedure

The anesthesiologist should visit the patient frequently during his postoperative course in order to observe the changes that have occurred following the operation and to be cognizant of these effects prior to succeeding anesthesia

Local Anesthesia

General anesthesia is not always required in order to obtain grafts to cover small areas A small amount of a local anesthetic agent may be given and then a graft may be removed and applied In extensively burned patients, major operative procedures may have to be carried out under local anesthesia because the condition of the patient is such that he cannot tolerate an inhalation anesthetic

Zylocaine or procaine (0 25 per cent) may be infiltrated in the subcutaneous tissue When a weak solution of the anesthetic agent is used a larger volume can be injected in the subcutaneous tissue making a smoother surface from which to obtain a graft A weak local anesthetic agent is quite satisfactory because anesthesia of only short duration is required A Pitkin s syringe is particularly useful for injecting local anesthetic agents (see Chapter 5)

EMOTIONAL FACTORS IN THE CARE OF BURNED PATIENTS

When a severely burned patient is admitted to the hospital he not only is in a state of severe physical pain but he is also undergoing serious emotional disturbances. Many burned patients are difficult to manage because they are unable to adjust to their physical incapacity and to their surroundings Emotional instability is reflected in abnormal behavior some are noisy loud and demanding others are markedly depressed and sullen often refusing to cooperate with the staff It is important for the doctors and nurses responsible for the care of patients to have some understanding of the important adaptive problems and of the adaptive mechanisms that patients use in an attempt to cope with their problems.[6]

Adaptive Problems

The primary problems to which a recently burned patient must adapt himself are threat to survival, fear of disfigurement prolonged physical discomfort, frequent anesthesia and surgical procedures, and a long, tedious convalescence (Table 5)

Table 5. Adaptive Problems in Burned Patients

PRIMARY	SECONDARY
Threat to survival	Separation from emotional gratification
Fear of disfigurement	Fear of rejection
Physical discomfort	Emotional pain from accident
Repeated operations	Effect of injury on future plans
Long convalescence	Conflict over dependency

In addition to these primary adaptive problems, others appear in varying combinations as secondary adaptive problems These include separation from family and friends, feelings of inadequacy and rejection, emotional overtones associated with the accident, possible effect of the injury on future plans, and conflicts engendered by a state of utter dependency (see Table 5)

Sometimes a patient believes that the burn was caused by his own negligence or through the fault of a close friend Patients may have strong feelings of guilt, especially if one of their loved ones was burned in the same accident. Separation of the patient from his family and friends deprives him of one of his main sources of emotional gratification at a time of great need Sometimes a feeling of loneliness leads to depression and self pity Some patients are disturbed by the enforced extreme dependency on others Many patients particularly women, interpret their injury as a threat to their capacity to be loved These patients are often hypersensitive to the slightest indication of personal rejection and they need to be constantly reassured One of the most important adaptive problems is the effect of the injury on future plans of the individual The patient whose livelihood depends on the use of his hands is tremendously disturbed by burns of that area Patients who have been active in athletics are particularly disturbed by burns of the lower extremities Not infrequently patients worry about the possible amputation of an extremity

Adaptive Mechanisms

The multiple severe psychologic threats involved in a nearly fatal injury cause a patient to be placed in the dangerous situation of becoming overwhelmed by physically and emotionally painful stimuli

The major initial responses are repression and suppression of unpleasant thoughts feelings and sensations The patient s attitude is that he will not think about these unpleasant things and above all he will not allow himself to have any feeling

At times a patient may so completely shun the reality of his problems as to present a grotesque clinical picture Hopelessly burned patients may indicate in their conversation that they consider their injuries to be trivial and that they expect to return home in a few days Euphoria is not uncommon in the first two or three postburn days. It is often followed by a long period of disorientation that is on a psychogenic basis in many instances.

Friendly personal contacts provide elements of hope that may aid the patient in giving up emergency repressive and constrictive techniques and in substituting mechanisms of constructive appraisal and planning, as well as direct action Visitors and friendly patients diminish the feeling of separation and fear of the incapacity to be loved If a patient is encouraged to attempt some constructive activity early in his treatment this may remove the conflict over his dependency and make him feel that he is contributing some direct action toward his future recovery The physician and nurse must encourage a patient to think constructively about his future plans

Prevention and Treatment of Emotional Disturbances

It is essential that the physician and the nurse understand the general nature of the patient s adaptive problems and assist him in the use of his adaptive mechanisms in order to achieve a psychologic adjustment Effective burn therapy involves not only the management of the physical injury but also a constant effort to make the situation less difficult for the patient and more bearable emotionally The management of the patient s adaptive problems is closely related to his physical care It is essential for a patient to have confidence in the competence of the staff Many burned patients are deeply discouraged and see little prospect of recovery but they do exhibit a form of primitive childlike faith in the ability of the physician This faith of the patient needs to be stimulated by an attitude of genuine interest on the part of all attendants Blocker has pointed out that each day the physician must sit at the patient s bedside if only for a short time and give assurance of his sincere concern

Severely burned patients are better off in a ward than in a private room If several patients have been involved in the same accident placing them in the same cubicle is particularly beneficial to group morale When a staff of several physicians is active on the ward it is essential for one physician to assume primary responsibility in all

phases of the care of a patient. It helps the patient to be able to refer to one of the physicians as his doctor This physician then maintains close contact with the patient's family He eases their apprehension and, in this indirect manner he reassures the patient

Visual evidence of the likelihood of uneventful recovery is particularly encouraging in the early phase of hospitalization Contact with patients who have had similar burns and are almost recovered is an important source of encouragement Many patients are reassured by seeing photographs of other severely burned patients showing burned areas at the time of injury and after recovery Such photographs are particularly valuable for orientation of families and friends

It is interesting that patients who have recovered from severe burns often seem quite reluctant to help those who are acutely ill Evidently they are striving to forget the physical and emotional suffering they have endured, and any contact with others who are suffering from thermal injury reminds them of their own painful experiences Nevertheless their presence on the ward is helpful as it reassures those who are just beginning to convalesce

Isolation of patients should be avoided as much as possible Early in the course of treatment diversional measures such as reading music and motion pictures are helpful Patients should be encouraged to manifest friendly relations with visitors, other patients, and ancillary personnel such as social workers and Red Cross workers.

During the first two weeks a patient is usually too frightened and bewildered to ask about his condition After the acute effects of the injury have diminished however, he begins to ask questions It is most helpful at this time to explain what can be expected in the ensuing months The physician should be as encouraging as he can be yet he must be honest

Anxiety on the part of a patient can be avoided frequently providing the physician anticipates it Usually a patient is most anxious about the expected length of hospitalization and the effects of the injury on his appearance and the functioning of the burned area The possibility of permanent physical disfigurement may be particularly distressing to women

Edema of the eyelids rapidly closes the eyes, and patients who sustain facial burns are frequently terrified by the idea of the possible loss of vision It is helpful to give emphatic reassurance on this point and usually this can be given truthfully

PAIN Treatment of a severe burn is accompanied by some pain and minor physical discomfort persists over a long period Physical pain is considerably less severe however than is generally supposed

In contrast, emotionally induced pain is a much more serious problem than is generally recognized. Frequently patients do not distinguish between physical pain and emotional tension and, regardless of origin, report all discomfort as pain. The physician and nurse must realize that burned patients need not only relief from pain but also *relief from fear. If all the complaints of a patient are treated with narcotics,* he may rapidly become an addict, at least emotionally. In patients whose emotional needs are neglected, regressive behavior sometimes occurs as manifested by moaning, complaining, and demanding.

Physical pain should be treated with narcotics. When the patient is particularly fearful and tense, some type of relaxing sedation may prove highly beneficial.

Assisting the Recovery Mechanisms of a Patient. Useful adaptive mechanisms should be encouraged as soon as possible. A patient's capacity for direct action is quite limited at first but increases progressively with time. Since the maintenance of nutrition is a crucial part of burn therapy, the patient is informed that eating the prescribed foods and protein supplements is one way in which he can hasten his recovery. As soon as a patient convinces himself that he can take an active part in improving his situation, his adaptive problems become *less terrifying. A physician assists the patient in developing a normal* outlook both physically and mentally by encouraging constructive activities. If he is inspired to help himself, his conflict over physical dependency upon others may be overcome. It is important for a patient to have a realistic evaluation of his limitations and a realistic appraisal of his potentialities. He must be given guidance and encouragement to plan and execute the required procedures for future vocational and nonvocational activities.

The entire program of emotional rehabilitation is the direct responsibility of the attending physician. The need for expert psychiatric assistance is rare. For a detailed discussion of emotional problems in severely burned patients, the reader is referred to an article by Hamburg.[7]

NURSING CARE OF BURNED PATIENTS

The care of a severely burned patient demands the highest caliber of bedside nursing. *The nurse is given more responsibility in the care of the severely burned patient than in almost any other type of serious illness.* It is extremely important that she be an integral part of the "team" of people caring for the burned patient.[8]

Frequent conferences between the physician and the nurse are extremely important, particularly in the initial phases of treatment. The nurse must have some understanding of the burn problem. Part

of this may be obtained by contact with the physician but it is also important that she become acquainted with modern concepts in burn care by reading recent periodicals and textbooks (see Chapters 2 3 and 4) With an understanding of the burn problem, she should be able to anticipate the needs of the physician

Materials required at the bedside at the time of admission of a severely burned patient are listed in Table 6

Table 6. Materials Available at Bedside on Admission of a Burned Patient

1 Masks	6. Intravenous set, with anticipated fluids
2. Tracheotomy set	7 Venous cutdown tray
3 Thermometer blood pressure cuff	8 Urinary catheter tray
4 Sterile dressing tray	9 Aspirating apparatus
5 10 cc. aspiration syringe and laboratory blood tubes	10 Oxygen
	11 Stryker frame

Role of the Nurse in Replacement Therapy

The nurse is responsible for adjusting the rate of administration of various fluids during the early phase of treatment in accordance with the physician s orders She maintains a detailed, accurate record of intake and output. These records must be kept up-to-date in order that the physician may study them each hour if necessary (Fig. 5) The physician makes his estimate of the amount and type of therapy needed on the basis of these records Since the best sign as to adequacy of treatment during replacement therapy is urinary output, the type of therapy prescribed is often based on the record of the hourly output of urine Usually the physician asks the nurse to adjust the rate of administration of fluid in accordance with the output of urine

During the first week of therapy, most burned patients require vitamins, antibiotics and intravenous injections of electrolytes and glucose in water Generally it is the nurse s responsibility to mix several solutions for simultaneous intravenous use The orders for various intravenous solutions must be exact, they must be written by the physician with specific indications as to time to be started, as well as duration of administration Whenever a mixture of solutions causes a precipitate infusion should be withheld until the physician is consulted. If several solutions are to be given at various times during the day, a nurse must plan for the entire 24 hours and make an even distribution for administering the fluids over that period All bottles should be labeled clearly as soon as solutions are mixed (Fig. 90) It may be necessary occasionally to give only a part of some mixtures at one time then the remainder is stored in a refrigerator for later infusion This procedure requires the close cooperation of physician

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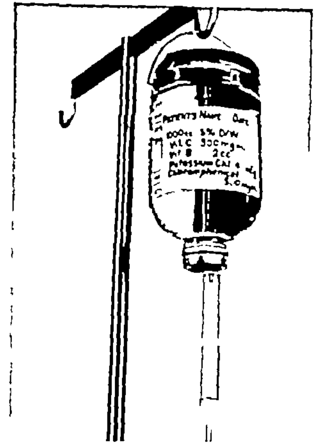

Fig 90 When several drugs are given in the same infusion, the bottle should be labeled. This prevents errors and simplifies the administration of complicated intravenous therapy

and nurse in order to obtain a clear understanding of the type of solution the time of administration and the rate of administration

MANAGEMENT OF INTRAVENOUS CATHETERS All severely burned patients must have an intravenous lifeline in the early postburn period This is obtained by using either a cutdown cannula or a femoral cannula *Usually a measured segment of a plastic catheter is* inserted into the vein It is the nurse s responsibility to see that there are no kinks in the catheter and that the extremity is properly anchored in order to prevent the catheter from being pulled out of the vein The dressing about the cannula should be changed as often as necessary to keep it clean and to prevent infection In changing dressings the nurse must be particularly careful not to cut the catheter at the skin edge and cause it to be lost in the vein

Many physicians recommend the installation of 0 5 cc of aqueous heparin and 0 5 cc of saline into the tubing every four hours to prevent plugging and clotting at the tip (see Chapter 2) Spasm in the vein sometimes inhibits a free flow of fluid Whenever the intravenous

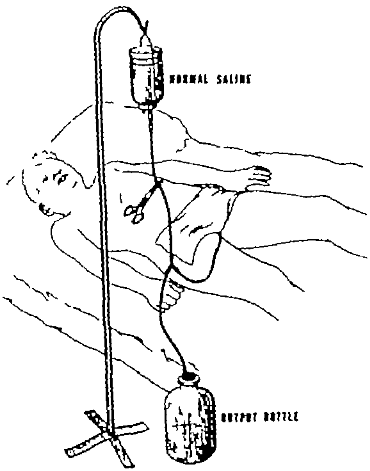

FIG 91 Diagram of an acceptable method of urinary catheter irrigation. The urinary catheter should be irrigated about every six hours. The clamp is removed from the tubing attached to the bottle of irrigating fluid and applied to the tubing attached to the output bottle, allowing the bladder to fill. Then as the clamp is removed and replaced on the tubing from the irrigation bottle, the bladder empties. This type of apparatus permits a closed, aseptic system and simplifies the irrigating procedure.

fluids fail to run freely through the catheter, the doctor should be notified immediately

CARE OF URINARY CATHETER An indwelling urinary catheter is inserted into a patient sustaining burns of more than 25 per cent of his body surface This catheter is usually allowed to remain in place until the problem of replacement therapy no longer exists The catheter should be irrigated with 0.25 per cent acetic acid or normal saline solution every six hours The amount of saline to be used should be recorded on the intake sheet generally about 100 cc. are sufficient If the catheter is to remain in place for an appreciable period of time, a sterile irrigation set may be attached at the bedside (Fig 91)

Catheters are usually changed at least once a week It is the nurse s responsibility to position the catheter in such a way that it will remain free from tension Whenever tension is placed on the catheter undue

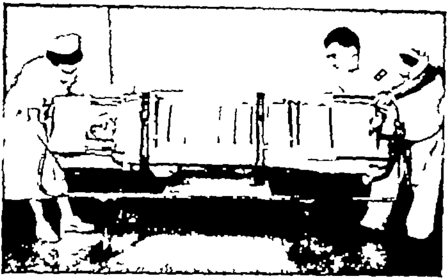

FIG 92. The Stryker frame simplifies the nursing care of severe burns. Although the patient may be turned by one individual, it is easier when two people carry out the turning procedure. A strap should be applied around the frame to give support. A second strap may be applied around the arms so they will not dangle during turning.

pressure may be exerted on the bladder neck and this may cause necrosis of the bladder wall The catheter should be kept clean to prevent contamination Frequent observations must be made to detect any leaking about the catheter or any evidence of purulent drainage

Use of the Stryker Frame

The Stryker frame is very useful in the management of patients having extensive burns [4] A large burn wound is extremely painful and the Stryker frame facilitates gentle handling and turning of a patient It eliminates the need for lifting a patient when he uses the bedpan It also makes general nursing procedures more easy to carry out The linen may be changed on the posterior frame while the patient is resting on his abdomen likewise the linen on the anterior frame may be changed easily when the patient is lying on his back

Patients having extensive burns may have to spend a long period of time in bed and decubitus ulcers may develop A patient can be turned easily four to eight times a day on the Stryker frame Such care eliminates prolonged undue pressure on any one area When the patient is on the anterior frame better nursing care may be given to the posterior portion of the body A patient may be kept on one side of the frame for four or five days after grafting on the other side of his body This procedure helps to prevent the collection of dependent edema fluid beneath new grafts

When a patient sustains an extensive burn and large circumferential areas need to be exposed he may be turned on the Stryker

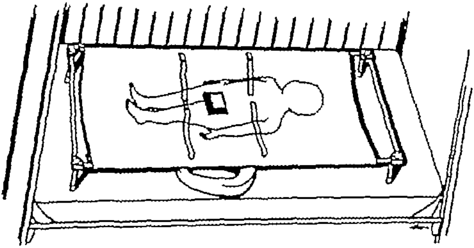

FIG. 93. An easily constructed frame for use in a crib. This facilitates the nursing care of a burned infant.

frame every two hours in order to allow drying of first one and then another exposed surface.

It usually takes two people to turn an adult easily (Fig 92) If a patient is unable to keep his arms close to his sides a strap may be used to hold his arms in position If the Stryker frame is properly padded, children are handled easily A frame may be constructed for use in a crib to facilitate handling of a burned infant and simplify nursing care (Fig. 93) [1] Usually a child is easier to care for than an adult because there is less strain in lifting and turning him

The legs of a Stryker frame may be lengthened to elevate either the top or the foot of the frame. A patient lying on the Stryker frame may be restrained easily by placing a pillow and a strap over his knees

A patient is subjected to a great amount of discomfort when he is transferred from his bed to a cart in order to be taken to the operating room Since a Stryker frame is on wheels a patient may be moved to the operating room without transfer to a cart. He may be anesthetized on the frame and then be removed to the operating table under anesthesia This not only decreases the amount of discomfort to the patient but eliminates frequent lifting by attendants The patient may be taken outdoors, to a television room, to the movies, or to the physiotherapy clinic on the frame. A patient derives a psychologic benefit in being moved from place to place

When a patient is lying on the anterior frame, his eyes are approximately 15 inches from the platform This distance is comfortable for reading and writing A patient can also feed himself quite comfortably when lying on his abdomen because the tray rests on the platform (Fig. 94) A footboard may be attached to the frame to support the feet of patients whose legs are severely burned When the patient is on

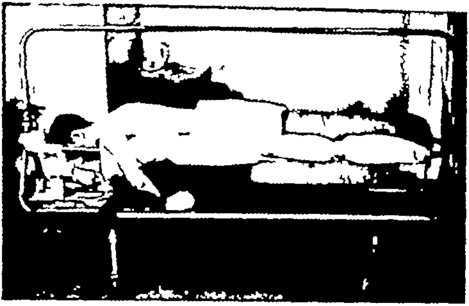

FIG 94 The patient on a Stryker frame can easily feed himself while he is resting on his abdomen The platform below the face is approximately 15 inches away This is an ideal distance for reading.

the posterior frame he can easily grasp the overhead bar and adjust his position Attachments may be placed on this bar to enable him to perform various types of occupational therapy

Positioning for Exposure

The nurse s ability to care for a patient treated by the exposure method requires an understanding of this type of treatment (see Chapter 4) Exposure is an accepted method of local care for an acute burn wound It is necessary however that the affected part be completely exposed The nurse must assist the physician in maintaining the proper position for exposure Circumferential burns of large areas may be exposed by using a Stryker frame and turning it frequently Partial thickness burns of the hands do well when treated by exposure, but they must be kept in a position of function It is imperative that the nurse encourage a patient to maintain his hand in the proper position

One of the most important aspects of nursing care and treatment by exposure is to keep the patient free from air currents When a burned surface is first exposed air currents are most uncomfortable Usually a cradle is placed over the bed lights should not be attached because a warm environment bacterial prolifera tion Sometimes it may be necessary to hot water bott around unburned areas in order to comfortabl night

The nur observe the p y and warm

Fig 95 This photograph shows the typical arrangement for a nurse carrying out the change of wet dressings. The sterile tray is at her left. Sterile gloves and a mask are worn during a change of dressing. The old dressing is removed with less pain if a bulb syringe is used to wet the dressing.

against picking at the crust of an exposed burn Children quite frequently pick at a crust and sometimes it is necessary to restrain their hands

Wet Dressings

Wet dressings are of considerable benefit in treating burns but they are time-consuming (see Chapter 5) They must be kept wet constantly in order to exert a beneficial effect. The usual procedure is a change every four hours and sometimes more frequently The wet dressing is occasionally changed only twice a day in dressings over large areas such as an entire lower extremity, but it is kept wet between changes by frequent applications of normal saline

A patient is usually apprehensive about the change of a wet dressing until he realizes that the nurse will be careful not to cause undue pain. These changes will not be painful if they are performed gently and painstakingly Narcotics are of little value in preventing pain

The nurse usually sets up at the bedside a sterile tray complete with wet dressings She wears sterile gloves and a mask The old dressings are removed as gently as possible The gauze pads may be removed more easily and less painfully with the aid of an irrigating syringe (Fig 95) Loose dead tissue is removed but any attached eschar is not disturbed Great care is taken to avoid pain and bleeding. If a

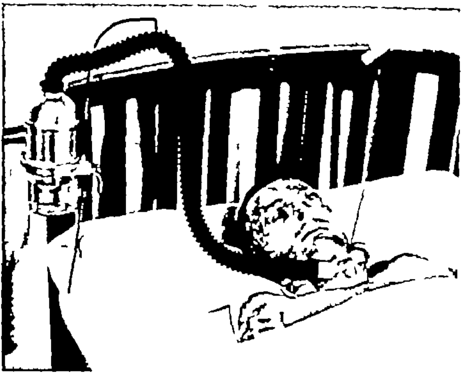

FIG 96. There are several methods of humidifying the air about a tracheotomy Usually the application of a moist sponge over a tracheotomy tube is sufficient. In some instances, it may be necessary to use an apparatus similar to the one shown in the photograph. Oxygen is bubbled through the fluid in the Mistogen apparatus. This apparatus assures the inhalation of moist air at all times and prevents crusting in the upper respiratory tree.

large dressing is to be applied at a change of dressing it may be necessary for an assistant to hold the extremity Fresh, wet saline pads are applied over the burn wound The size of the pads depends upon the extent of the area covered by the wet dressing The gauze pads may be 4 x 4 inches 4 x 8 inches or 16 x 16 inches A dressing is more comfortable when applied with warm saline, however it is not necessary to keep the dressing warm

Care of Tracheotomy

A tracheotomy is required in many severely burned patients, especially for those patients sustaining respiratory tract irritation or deep burns about the face and neck (see Chapter 6) Nursing care is extremely important following a tracheotomy [10]

A clean dressing must be kept around the tracheotomy tube to cover the tracheotomy wound until healing is complete Humidification of the inspired air is required for all acutely ill patients who have a tracheotomy in order to prevent drying of the mucous membrane as it favors the formation of obstructing mucopurulent plugs. This may be accomplished by placing a damp sponge over the tracheotomy

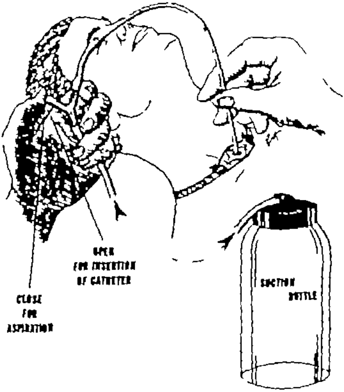

FIG. 97 The insertion of a Y tube into the suction line permits fingertip control of suction during aspiration of the trachea The catheter should be inserted into the trachea without any suction. As it is withdrawn, the fingertip can be used to close the Y tube and suction may be applied as the catheter is being removed. This procedure prevents irritation and trauma to the mucous membrane of the trachea.

opening and keeping it moist. Other patients may need some type of humidifying apparatus (Fig 96) It has not been determined whether antibiotics or enzymes placed into the tracheobronchial tree reduce pulmonary infection and assist in liquefying secretions

The inner cannula must be taken out and cleaned at least every eight hours The tracheotomy tube should be changed at least every four days This procedure is accomplished usually when the burned patient is taken to the operating room for a dressing change or graft The obturator must be kept strapped to the bed to facilitate reinsertion of the tracheotomy tube if it should come out It is extremely important to make sure that the tracheotomy is functioning well before a patient is turned on his abdomen Sometimes the curved tracheotomy tube pinches against the side of the trachea and produces respiratory obstruction

Unless suctioning is carried out properly, the tracheal epithelium may be damaged, and tracheobronchitis atelectasis and bronchopneumonia may occur Too vigorous tracheal suction is the most frequent error in the management of a tracheotomy A Y-tube should be inserted into the suction line in order that the vacuum may be released by fingertip control (Fig 97) Usually a No 12, firm rubber or

plastic catheter is used The tracheal catheter must be kept scrupulously clean to prevent contamination and infection Two separate trays are kept at the bedside containing a 5 per cent sodium bicarbonate solution (or a Zephiran solution) one for nasal catheters and the other for tracheal catheters The tracheal catheter is never used for aspiration of the nose because of the fear of cross-contamination The catheter should be inserted into the tracheotomy to the full depth desired withdrawn approximately 1 cm to remove the tip from the mucous membrane and then with the fingertip the Y valve is closed to obtain suction Each aspiration is limited to about fifteen seconds Unless secretions are extremely profuse an interval of approximately three minutes rest is allowed between aspirations

The head may be turned to the right to aspirate the left bronchus then it is turned to the left to aspirate the right bronchus Gentle suction carried out with the best possible aseptic technique decreases post tracheotomy tracheobronchitis and hemorrhagic tracheobronchial secretions

Care of Eyes

In treatment of burns about the eyelid an important objective is to keep the cornea moist in order to prevent ulceration and infection The eyes should be irrigated with normal saline by means of a bulb syringe at least every six hours and sometimes more often After irrigation an antibiotic ophthalmic ointment should be instilled If the lids are not in apposition a moist pad must be kept over the eye to prevent drying of the cornea This is especially important at night A nurse must be careful to reassure a patient that he will be able to see as she gives eye care Sometimes it is wise to pull the eyelids apart in order for a patient to be convinced that he actually can see Such strategy is quite impressive especially if he has visitors If some corrective measure is to be carried out on the eyelids it is important to tell a patient before the operation about the type of procedure involved informing him that he will be unable to see for several days because his eyes will be bandaged (see Chapter 6) When patients have eyes that are closed because of edema or because of a bandage it is advisable to speak to the patient before he is touched for any nursing procedure

Care of Donor Sites

Donor sites may be treated with occlusive dressings or by the exposure method (see Chapter 5) If the sites are treated by dressings the nurse must be sure that the patient does not pick at the dressing and cause contamination of the area If the donor site is treated by the exposure method it must be kept completely exposed to the air Im

mediately after skin has been removed, exposed donor sites are somewhat uncomfortable, it is therefore advisable to keep them free from air currents Postoperatively a patient usually requires narcotics for the first 24 hours. The nurse must make sure that the exposed donor sites do not touch the bed clothing A patient may have a tendency to pick at the crust as healing progresses and thus may lead to infection The nurse may trim away any loose areas of crust as they appear, however, the crust must not be pulled away as long as it is attached It should be allowed to fall off

Responsibility of the Nurse in Nutritional Therapy

The survival of a severely burned patient may depend upon nutritional replacement (see Chapter 8) The nurse is responsible for making sure that a patient is given the full amount of intake prescribed by the physician This usually means that the patient routinely receives between meal feedings of a high-protein supplement Frequently the nurse has to feed a severely burned patient to make sure that he takes the necessary supplemental feedings

When tube feedings are used a patient must be observed frequently to be assured that gastric dilatation does not occur Usually such feedings are administered through a plastic nasogastric tube It is mandatory that nurses have an understanding of nutritional requirements of burned patients Only by their close cooperation with the dietitian and the physician can proper nutritional therapy be achieved

Rehabilitation

In some well-staffed institutions, most of the rehabilitation of a burned patient is carried out by physical therapists and occupational therapists In other institutions, it is the responsibility of the nurses to carry out rehabilitation under the direction of a physician It is important for a patient to maintain muscular tone of all unburned areas. This can be accomplished only by insistence upon routine exercises for unburned areas (Fig. 98)

As soon as a burn wound has healed active and passive movements are initiated These simple movements must be carried out several times a day and usually they are conducted under the nurse's supervision The patient should be encouraged to do things for himself as rapidly as possible If his upper extremities have been injured he should be encouraged to brush his teeth and feed himself as soon as he can After burns of the legs, the patient should be shown how to contract his quadriceps muscles and move his ankles Such exercises should be performed several times a day After a sufficient number of exercises have been carried on in bed, a patient is permitted to get out

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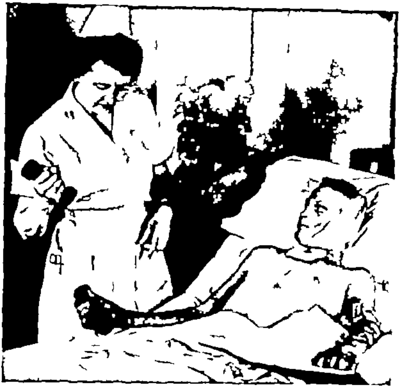

FIG 98 *It is important that muscular tone be maintained during the several weeks of bed rest. The nurse should teach the patient to carry out daily exercises of unburned or healed extremities.*

of bed Burns of the legs necessitate wrapping with rubberized elastic bandages before a patient is allowed to stand If a patient sustains burns of the hands, he can assist in the return of function by active motion in a pan of warm water every four hours

Psychologic Support

There is no aspect in the therapy of burns in which a nurse can be more decisively helpful than in the promotion of a patient s emotional well being The nurse must avoid attitudes of callousness, as well as of oversolicitude If a nurse is somewhat unstable emotionally she will tend to react to a patient s complaining with one or the other of these extreme modes of behavior Callous treatment reinforces the patient s *fear of rejection oversolicitude may promote regression to childlike* behavior The good nurse, trusting in the intuition for which her sex is renowned, manages to be kind but firm It should not be supposed that a kind friendly warm and sympathetic approach is incompatible with firmness

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CHAPTER 11

Complications of Burns and Burn Therapy

THE ROAD to recovery from a severe burn is beset with many complications. The seriousness of the injury, the frequent administration of anesthetics and frequent operations, the large wounds, the prolonged period of bed rest and the large number of other procedures required in therapy all predispose to the occurrence of a wide variety of complications. Many complications are really complications of essential therapy.

Most of the complications of burns are related to infection (see Chap. 7). In this chapter some noninfectious complications are considered. The most difficult problem in the management of burned patients is often the treatment of some of these complications. Recognition of the more common complications aids in the institution of effective prophylactic measures.

COMPLICATIONS INVOLVING THE RESPIRATORY TRACT

Most respiratory derangements complicating burns occur following respiratory tract damage due to inhalation of noxious agents and gases (see Chap. 6). However, other respiratory tract disorders occur as complications of the burn or of anesthesia.

In children and elderly individuals pneumonia is not uncommon. It usually follows a prolonged period of bed rest with the patient lying in one position. Changes of position, particularly by the use of the Stryker frame, may prevent the development of pneumonia. Sometimes pneumonia follows the use of a gastric feeding tube in children. Deep burns around the chest prevent adequate coughing. In some seriously burned patients the cough reflex is diminished. Whenever the patient is unable to remove secretions from the tracheobronchial tree, tracheotomy should be performed.

Atelectasis may develop after one of the many anesthetics required in the management of burned patients Atelectasis also occurs following aspiration of gastric contents as a complication of tube feedings or after anesthesia Aspiration of gastric contents is more common in children than in adults When patients are receiving tube feedings care should be taken that the stomach is not overdistended and that the patient has adequate opportunity to cough particularly when he is turned from side to side Aspiration of gastric contents is liable to occur when a patient with a full stomach is turned on his abdomen

COMPLICATIONS INVOLVING THE GASTROINTESTINAL TRACT

Acute dilatation of the stomach may occur at any time during the entire course of the burned patient It is more common than is usually recognized It may occur during the first week after injury and is not uncommon as a complication of tube feedings It frequently accompanies septicemia Acute distention of the stomach may develop during oxygen therapy if the oxygen is administered by a nasal catheter

The stomach may be enlarged due to simple gaseous distention or it may be acutely dilated with fluid Acute dilatation of the stomach is characterized by regurgitation of fluid upper abdominal distress, dyspnea dehydration and, if untreated circulatory collapse The early symptoms are expectoration of small mouthfuls of fluid The patient does not vomit but merely spits out the overflow Anorexia and nausea occur but pain is rarely severe A persistent hiccup may accompany eructation and regurgitation.

The exact mechanism of acute dilatation remains obscure However it is generally believed that dilatation is caused by reflex inhibition of the gastric motor mechanism Gastric atony appears to be a part of the generalized ileus that develops under many different circumstances In addition, patients with severe burns may be unable properly to control the epiglottis, and may thus swallow large amounts of air This leads to gaseous distention and progresses to acute dilatation

The most important phase in treatment is recognition If over distention of the stomach is suspected, the correct diagnosis can usually be made by palpation and percussion Whenever there is doubt a Levine tube should be inserted in the stomach

Paralytic ileus is a very common complication of burns In most burns of more than 45 per cent of the body surface peristaltic activity is absent during the first few post burn days For this reason extensively burned patients should not receive food by mouth until there is evidence of good peristaltic activity When peristalsis becomes

FIG. 99 Roentgenogram of a patient who developed a stricture of the esophagus. The stricture, seen between the two arrows, developed after a rubber intragastric feeding tube had been in place for a period of six weeks. This is an unusual complication. The patient had a very extensive burn complicated by Curling s ulcer and septicemia He required supportive nutritional therapy for a long period of time. The stricture was corrected by means of repeated dilatation.

audible feeding may be begun cautiously In general, it is not safe to begin tube feeding during the first postburn week

Paralytic ileus after burns appears to be a nonspecific manifestation of severe injury Usually the ileus persists only a short time and disappears as the patient s condition improves Persistent paralytic ileus is a common manifestation of septicemia.

Fecal impactions are not uncommon Prolonged immobilization predisposes to their occurrence Too often the physician is so busy attending to the many urgent facets of burn care that he neglects routine management of the bowels In seriously burned patients, it is advisable to do a rectal examination at the time the patient is under anesthesia for grafting or a dressing change

Esophageal stricture, a rare complication may follow prolonged use of an indwelling nasogastric tube for feeding purposes (Fig 99) *Such strictures are usually benign and respond to esophageal dilatation* They usually manifest themselves several weeks after the patient is completely healed

Curling's Ulcer

In 1842, Curling reported twelve cases of gastrointestinal ulcerations complicating thermal burns There are numerous theories as to

the cause of this type of ulceration[3] The most commonly proposed theories are (1) that the ulcer is related in some way to hemoconcentration in the wall of the stomach and duodenum and (2) that the ulcers result from either failure or hyperactivity of the adrenal gland Although it has been demonstrated that there is an increase in the level of blood histamine in burned animals, there is no evidence that the elevated levels of blood histamine play any part in the formation of Curling s ulcer Necheles and Olson have reported an increase in gastric secretions and acidity following burns in a small series of dogs[2]

About 150 cases of Curling s ulcer have been recorded in the literature Twenty cases have been reported from the Surgical Research Unit at Brooke Army Medical Center The incidence of gastrointestinal ulcer in burned patients admitted to the Brooke Army Hospital over a six year period was 2 per cent. The autopsy incidence of acute ulceration following burns was about 21 per cent Curling s ulcer developed in patients who had extensive burns The average per cent of total body surface burned in the cases complicated by ulcer was 61 per cent, including a third degree component of 42 per cent. In this series of 20 patients, only 3 survived[1]

It is conceivable that a larger number of patients with Curling's ulcer survive It is difficult to diagnose the lesion unless some type of catastrophe, such as massive bleeding occurs. Frequently there are no signs or symptoms of ulcer formation The patients may complain of some abdominal discomfort and, if a gastric tube is in place, small amounts of blood may be seen The first sign is usually related to acute hemorrhage or perforation Not infrequently ulcerations develop and are completely unrecognized until discovered as an incidental finding at autopsy Ulcers may develop as early as the first or second post burn day but the usual time for manifestation of hemorrhage is between the first and third weeks following injury

The ulcer is most frequently located in the duodenum (Fig 100) The ulcers may be multiple. Severe hemorrhage is usually caused by large single ulcers on the posterior wall of the first part of the duodenum.

Since the ulcerations occur in very extensively burned patients the cause of death is usually something other than a complication of the ulcer However in some instances severe hemorrhage or perforation and peritonitis are the primary cause of death

Usually only the more severely burned patients (greater than 35 per cent of the body surface) and those with burns complicated by other injuries or systemic infection develop ulcers which are recognized clinically All patients with major burns should be carefully questioned about abdominal complaints in the hope that gastro-

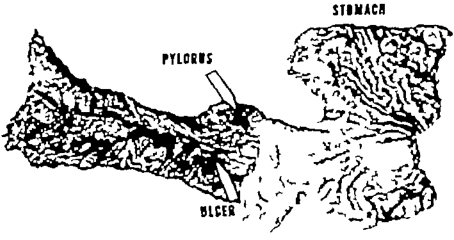

FIG. 100 Photograph of an autopsy specimen of a Curling's ulcer The ulcer was located on the posterior aspect of the first portion of the duodenum. The patient had a deep burn of 60 per cent of the body surface and died on the fourteenth postburn day from septicemia. There were no signs or symptoms referable to the ulcer

intestinal ulceration might be diagnosed. Minor complaints of epigastric pain are frequently overlooked while caring for the more obvious needs of a severely burned patient.

Since many extensively burned patients may develop Curling's ulcer prophylactic treatment of all patients in this category is recommended Antacids should be given during the first three weeks after injury The use of Banthine should be reserved for the onset of symptoms suggestive of gastrointestinal ulceration If hemorrhage occurs the patient should be treated energetically with blood Banthine and antacids Gastrectomy should not be considered unless the magnitude of hemorrhage is so great that operation is mandatory as a life-saving measure *Experience has shown that gastrectomy in severely burned* patients is almost invariably followed by disruption of the gastrointestinal suture line On this basis, the importance of a conservative regimen is emphasized Should operation be necessary for uncontrollable hemorrhage it appears that the procedure of choice would be exteriorization of the stomach with tube duodenostomy and a jejunostomy for feeding purposes This type of operation would eliminate the complications that follow leakage from sites of anastomosis

COMPLICATIONS INVOLVING THE GENITOURINARY TRACT

The most common complication referable to the genitourinary tract in burns is cystitis A certain degree of cystitis always follows the routine use of the indwelling catheter In children it is often

necessary to have a catheter in the bladder for a prolonged period of time in order to prevent soiling of the burn wound The catheter should be removed as soon as practicable Careful attention should be paid to frequent irrigation of the catheter and change of catheters every five days (see Chap 10)

After prolonged use of indwelling catheters in males, a periurethral abscess may form This follows irritation by the catheter and contamination of the urethra by bacteria from the burn wound Such abscesses require drainage. The trauma of a catheter may soften the urethral wall by inflammation leading to the formation of a urethral diverticulum. Acute epididymitis and orchitis sometimes occur Urethral stricture may follow prolonged use of the catheter with constant inflammation of the urethra This can usually be prevented by proper care of the catheter and early removal

Urinary calculi are not uncommon complications They may be present in the renal pelvis or in the bladder Bladder calculi are more frequent than renal calculi Recumbent posture made necessary by prolonged illness causes stasis in the urinary tract and leads to stone formation Infection in urinary tract adds to the stasis factor Prolonged bed rest is frequently followed by osteoporosis and withdrawal of calcium from the bony skeleton In addition dietary imbalances and increased calcium excretion in the urine are factors favoring stone formation

THROMBOEMBOLIC COMPLICATIONS

Deep venous thrombosis and pulmonary embolism are not common complications of burn injury This is rather surprising in view of the predisposing factors that are present in a burn (a severe injury, infection, and immobilization)

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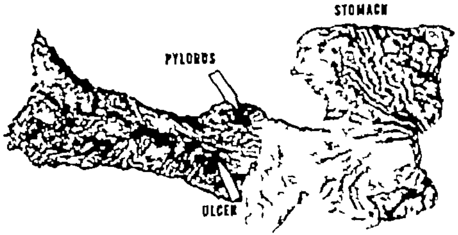

FIG. 100 Photograph of an autopsy specimen of a Curling's ulcer The ulcer was located on the posterior aspect of the first portion of the duodenum. The patient had a deep burn of 60 per cent of the body surface and died on the fourteenth postburn day from septicemia. There were no signs or symptoms referable to the ulcer

intestinal ulceration might be diagnosed Minor complaints of epigastric pain are frequently overlooked while caring for the more obvious needs of a severely burned patient.

Since many extensively burned patients may develop Curling's ulcer prophylactic treatment of all patients in this category is recommended Antacids should be given during the first three weeks after injury The use of Banthine should be reserved for the onset of symptoms suggestive of gastrointestinal ulceration If hemorrhage occurs the patient should be treated energetically with blood Banthine and antacids Gastrectomy should not be considered unless the magnitude of hemorrhage is so great that operation is mandatory as a life saving measure Experience has shown that gastrectomy in severely burned patients is almost invariably followed by disruption of the gastrointestinal suture line On this basis the importance of a conservative regimen is emphasized Should operation be necessary for uncontrollable hemorrhage it appears that the procedure of choice would be exteriorization of the stomach with tube duodenostomy and a jejunostomy for feeding purposes This type of operation would eliminate the complications that follow leakage from sites of anastomosis

COMPLICATIONS INVOLVING THE GENITOURINARY TRACT

The most common complication referable to the genitourinary tract in burns is cystitis A certain degree of cystitis always follows the routine use of the indwelling catheter In children it is often

necessary to have a catheter in the bladder for a prolonged period of time in order to prevent soiling of the burn wound. The catheter should be removed as soon as practicable Careful attention should be paid to frequent irrigation of the catheter and change of catheters every five days (see Chap 10)

After prolonged use of indwelling catheters in males, a periurethral abscess may form This follows irritation by the catheter and contamination of the urethra by bacteria from the burn wound Such abscesses require drainage. The trauma of a catheter may soften the urethral wall by inflammation leading to the formation of a urethral diverticulum Acute epididymitis and orchitis sometimes occur Urethral stricture may follow prolonged use of the catheter with constant inflammation of the urethra This can usually be prevented by proper care of the catheter and early removal

Urinary calculi are not uncommon complications. They may be present in the renal pelvis or in the bladder Bladder calculi are more frequent than renal calculi Recumbent posture made necessary by prolonged illness causes stasis in the urinary tract and leads to stone formation Infection in urinary tract adds to the stasis factor Prolonged bed rest is frequently followed by osteoporosis and withdrawal of calcium from the bony skeleton In addition, dietary imbalances and increased calcium excretion in the urine are factors favoring stone formation

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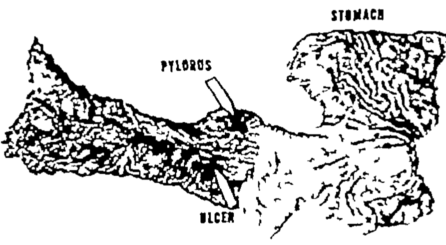

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FIG. 101 Bilateral ectropion. This is a common complication of burns of the eyelid. It can be prevented by tarsorrhaphy and early grafting. Once ectropion develops, a release of the contracture with overcorrection of the lid and application of a thick split-thickness skin graft must be performed.

COMPLICATIONS INVOLVING THE MUSCULOSKELETAL SYSTEM

The most common complication interfering with function in the burned patient is contracture Contractures may occur around any joint but are most common in the neck axilla and about the hands Prevention of contractures is accomplished by proper positioning of the affected parts and early skin coverage In some areas contractures are almost inevitable, but the severity of deformity may be considerably lessened by judicious early therapy Full thickness burns of the hands are frequently complicated by contractures Most third degree burns in the axilla and in the anterior portion of the neck are followed by contracture Such complications must be managed by reconstructive plastic procedures carried out months after initial skin coverage has been achieved

Contracture of the eyelids leads to ectropion formation (Fig. 101) If an ectropion develops and is not corrected the cornea dries and becomes ulcerated and infected Panophthalmitis may occur with loss of the eye Corneal ulcers can be prevented by proper eye care tarsorrhaphy and early grafting (see Chap 6)

Infectious arthritis may follow septicemia or burns around any joint Infectious arthritis is fairly common in burns of the phalanges. Infection about the hip joint and other larger joints is usually a complication of systemic infection

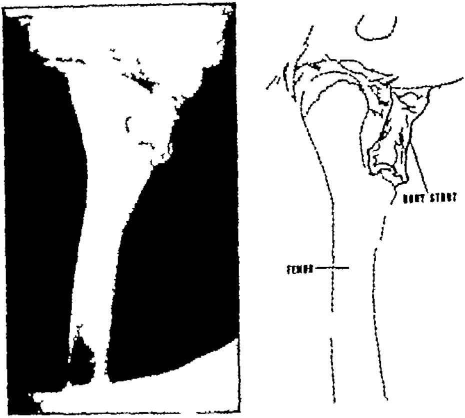

FIG. 102. Roentgenogram of the hip region of a patient who developed fascial calcification. The bony strut extended from the greater trochanter of the femur medial to the ischium. It appeared that this bony bridge was a calcification of the fascia in this area. The deformity first manifested itself six months after the patient had been discharged from the hospital. At operation, the bony bridge was removed. Postoperatively the patient had near-normal range of motion of the joint.

Osteomyelitis is a rare complication but does occur following deep burns in or near bone. After prolonged immobilization in bed a certain amount of osteoporosis develops. In patients who have been in bed for a year or more pathologic fractures sometimes occur. These usually follow demineralization of the bone due to prolonged negative calcium balance.

Calcium may be deposited in the fascia. Fascial calcification is usually seen about a major joint and may lead to marked limitation of motion (Fig. 102).

Nerve palsies are not uncommon in deep burns. This complication may follow direct nerve damage from the heat. Injury to the peroneal nerve resulting in foot drop is frequently seen following deep burns of the leg.

MISCELLANEOUS COMPLICATIONS

One of the most frequent and troublesome complications in burns is infection of the donor sites with conversion of the areas to granulating surfaces. Careful attention must be paid to the donor sites

FIG. 103 Photograph of the body of a patient whose donor sites became converted to granulating surfaces following infection. Several drums of skin had been removed from the body of the patient in an overseas hospital. The patient was transferred before the donor sites had healed. During transportation the areas became infected and converted to granulating surfaces. Prolonged transportation of patients with fresh donor sites is contraindicated. These areas were grafted, and the patient recovered.

because infection may destroy the remaining viable epithelium Occasionally when the donor site is taken too deeply the area fails to heal, and a granulating surface results. These areas must then be grafted Less infection occurs when donor sites are exposed than when dressings are applied (see Chap 5) Occasionally patients are seen whose burned surfaces are practically healed but whose donor sites have been converted to granulating wounds (Fig. 103)

Malnutrition may complicate a burn. Usually this follows inadequate therapy Severe malnutrition can be prevented by proper nutritional therapy and early skin coverage (see Chap 8)

In some extensively burned patients it is most difficult to prevent the development of decubitus ulcers These may occur in the sacral regions over the anterior superior iliac spine on the posterior aspect of the head and on the back of the heel In most instances the decubitus ulcer can be prevented by proper positioning of the patient particularly with the aid of the Stryker frame (see Chap 10) Pressure points must be observed frequently and every effort made to prevent the breakdown of skin in these areas

The burned patient is liable to all the complications that may be associated with operation such as cardiac arrest transfusion reactions and postoperative parotitis

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CHAPTER 12

Treatment of Burns in Disaster

WITHIN THE PAST two decades several civilian disasters have occurred in the United States in which large numbers of burned casualties were seen. The experiences in these disasters and the experiences of the armed forces during World War II and the Korean conflict have greatly improved our understanding of the problems of disaster care for burns.

The fire at the Cocoanut Grove night club in Boston on November 28, 1942, took the lives of 491 persons.[8] Excellent care for the survivors was made possible by prior planning and organization for such an emergency. Injury of the respiratory tract presented the most pressing problem of therapy. Valuable information was obtained about the diagnosis and treatment of respiratory tract irritation from noxious gases.

There were 125 persons burned to death on the lot, and 150 others were burned and admitted to various hospitals after the circus fire at Hartford, Connecticut on July 6, 1944.[11] This unusually large number of burned patients could be managed effectively because of the prior planning and organization of the Hartford Hospital. There were no deaths in the first 48 hours because vigorous fluid therapy was instituted promptly.

Approximately 560 persons were killed and 800 persons were hospitalized when two ships exploded at the docks at Texas City, Texas, on April 16, 1947. Most of the patients received mechanical injuries but many were burned. In his discussion of the experience gained in this disaster, Blocker pointed out that a great many doctors are unaware of disaster problems. Local physicians in a disaster region, rather than medical assistance brought to the scene of disaster from the outside, are primarily responsible for the care of the sick

and injured Blocker expressed the conviction that a detailed disaster program for physicians should be active in every community [4]

On March 31, 1954, twenty burned casualties were admitted to the Edward J Meyer Memorial Hospital in Buffalo New York, from the Cleveland Hill school fire. Eleven patients were estimated to have burns in excess of 20 per cent of the body surface In reporting on this disaster Schenk pointed out the need for rapid screening of cases [10] He noted that 50 per cent of the cases required 95 per cent of the personnel's time. The efficient use of personnel and facilities was accomplished only after proper sorting

Enyart and Miller have given a detailed report on the disaster in which 203 casualties resulted from an explosion on the aircraft carrier USS Bennington on May 26, 1954 [7] The patients were treated at the Newport Naval Hospital Newport, R I All but 8 of the 82 hospitalized patients had severe burns Dextran and serum albumin were used effectively as resuscitative agents. The exposure method of local care was applied in the treatment of all patients, apparently with great success.

All of these experiences emphasize the need for organization and planning for disasters Since the development of thermonuclear weapons, there has arisen an even greater need for physicians to become acquainted with disaster care When Hiroshima with a population of 300 000 was devastated by an atomic bomb there were 80 000 to 100 000 injured 15,000 missing and 70,000 deaths. The highest percentage of the casualties were burns Thermonuclear weapons now are capable of producing approximately 1,000 times the explosive force of the bombs used at Hiroshima. A thermonuclear weapon is accompanied with the release of an enormous amount of kinetic energy At least 80 per cent of this energy is in the form of ordinary heat It might be expected that tens of thousands of burn casualties would result from a major thermonuclear attack

A SURVEY OF THE PROBLEM

It is obvious that certain compromises from ideal therapy must be made The quality of therapy varies in accordance with the number of casualties and the available personnel and supplies.

Different compromises in therapy may be necessary with each disaster Under conditions of thermonuclear warfare, it is apparent that a wide disparity would exist between the medical load imposed and the surviving medical assets at least during the early postdetonation period. In meeting the problem the extent of medical care given must be determined by two basic considerations

(1) providing of maximum care for the maximum number of patients and

(2) avoidance wherever possible of any procedures that might reduce a patient s ability to care for himself

Although it is difficult to specify definite details of therapy some generalizations may be made

(1) Policy decisions concerning the compromises that are necessary must be made by the person who is most experienced in casualty care The surgeon available at the scene of the disaster who has the greatest experience in the management of burns should accept the leadership for deciding and outlining necessary compromises in therapy

(2) Proper medical sorting is of paramount importance As Churchill has pointed out, ideal distribution of the injured does not occur in any unexpected catastrophe in a civilian community [6] With improper sorting, hospitals close to the scene are often swamped by the less severely injured who could well withstand transportation to more distant points

(3) Patients with minor injuries who can be easily rendered effective must be returned to duty

(4) There should be a maximum conservation of medical effort Trained medical individuals should not be assigned to first aid or rescue operations

(5) Essential supplies should be rigidly conserved

(6) Prior planning is extremely important Medical units should be organized for use in disaster Prior planning has been extremely effective in all civilian disasters, of course it is of greatest importance in all military medical operations

(7) The organization of ancillary personnel such as the police communication workers, supply workers and volunteers is extremely important.

TYPES OF BURNS

In most civilian burn disasters the injury is due to contact with flames. Thermal injuries resulting from thermonuclear blasts would be predominantly flash burns involving the exposed portions of the body Flame burns may occur after thermonuclear explosions owing to ignition of clothing and contact with burning materials

Evidence has been presented that radiation injury and thermal burns act synergistically in increasing mortality in experimental animals A thermal burn and exposure to radiation each of which alone is nonlethal in the majority of animals tested can produce a

high percentage of mortality when combined.[5] Death appears to be due to sepsis in the combined injury, and the mortality can be substantially reduced by antibiotic therapy [3]

The frequency with which combined thermal and radiation injury might be expected to occur in thermonuclear warfare is not known Treatment would have to be directed primarily at the thermal burn There is no specific therapy for radiation injury Antibiotics and blood transfusions, which are valuable in the treatment of burns, are also of supportive value in radiation injury The principles of treatment of burns resulting from thermonuclear explosions are the same as those applied in the common forms of burns

MEDICAL SORTING

Sorting, screening and triage are synonymous terms that refer to the sorting of casualties on the basis of urgency and type of condition presented The purpose of sorting is proper routing to medical units appropriately situated and equipped for therapy *Sorting is the key to the effective management of large numbers of burned casualties* Without sorting, an orderly and efficient utilization of available medical means is impossible.

Sorting is a continuing procedure that must be carried out at each stage of care It is a flexible procedure and should be performed by the most experienced surgeon in the area His decisions are based not only on the condition of a particular patient, but also on the number of injured requiring treatment and on the available facilities and personnel For example, a hospital with a limited supply of blood should utilize the blood so as to aid the recovery of the largest number of injured On this basis a critically injured man who would require all of the 10 pints of blood available would be assigned a lower priority for transfusion than 5 casualties who could probably recover if each received 2 pints of blood. On the other hand if large supplies of blood were immediately available, priority for treatment would be established by the severity of the wound

SORTING IN A MASS CASUALTY SITUATION

In most disaster situations, the most seriously injured patient receives the greatest priority However such a priority system is based on an unfailing source of supplies and on an abundance of medical personnel In an atomic disaster, it becomes evident that some modification of the usual priority system would have to be established

Percentage of body surface burned is the easiest method of determining the over all severity of the injury However each patient

should also be evaluated according to the depth of burn the area of involvement and the ambulatory state Since most of the burns are expected to be of the flash variety, a large number of partial thickness burns of relatively small extent may be expected to occur In burns that occur following secondary fires, the depth and extent of injury would be greater

Available knowledge points toward the fact that in a mass casualty situation the patient with second and third degree burn involving more than 40 per cent of his body would probably not survive This percentage might be a little smaller in persons under 18 months of age or over 50 years If mechanical and radiation injuries are also present, considerably less than a 40 per cent burn may be incompatible with survival. In the initial sorting such casualties should be placed in the group designated as expectant treatment and made as comfortable as possible [1] They should be given adequate doses of morphine if available and placed in the lowest priority group for definitive treatment They should not receive definitive therapy until all patients are cared for in higher priority groups.

The major effort should be directed toward administering therapy to the casualties having 15 per cent to 40 per cent involvement Some casualties with 20 per cent superficial burns might be discharged to self care Casualties with burns involving less than 15 per cent of the body surface could be discharged to self care if the location of the burns does not interfere with ambulation Although many individuals with burns of 15 per cent of the body surface are hospitalized in usual practice there is evidence that most of these patients could take care of themselves if they were supplied with water food, electrolytes and antibiotics However self care is not feasible if the casualty has a severe burn of the face or if an extensive burn of the leg makes ambulation impossible Such casualties would have to be referred to a holding facility where untrained personnel could care for their daily needs. Individuals with very minor burns might be utilized to help care for the more seriously injured

In the event of atomic disaster it is expected that most of the survivors would have burns of such configuration that they could care for themselves. Many casualties with full thickness involvement of small extent might be expected to care for themselves initially and receive treatment later in a medical installation where grafting could be performed A great deal of the sorting in a mass casualty situation might be carried out by the casualties themselves It would be hoped that those who could continue to carry on some type of work might make themselves most useful and not overburden the medical facilities

COMPROMISES IN THERAPY FOR DISASTER

There are several phases of emergency medical care in burns that are highly important These include (1) relief of pain (2) supportive therapy (3) management of the burn wound and (4) antibiotic therapy to aid in the prevention of infection

Relief of Pain

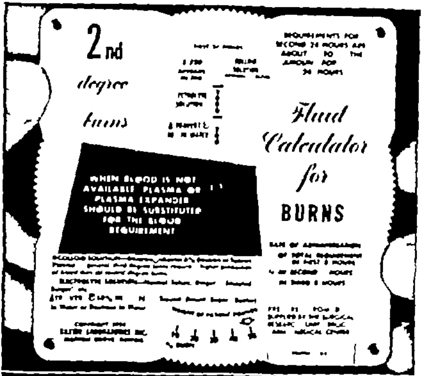
Full thickness burns are relatively painless, but partial thickness burns are quite painful for the first hour or two after injury If personnel and facilities are available, intravenous morphine should be given to allay pain and apprehension In a more extensive disaster it would be impossible to administer a narcotic Fortunately an exposed burn becomes relatively painless after a few hours If time permits and supplies are available, the burn wounds might be covered with a dressing, which leads to the prompt relief of pain and discomfort. In some situations a simple bland water soluble ointment might be applied for the temporary relief of pain In any extensive disaster, it would be wise to disseminate the information that partial thickness burns become painless as soon as a dry crust has formed

Supportive Therapy

Proper supportive therapy includes the infusion of adequate amounts of blood, plasma or Dextran electrolytes and water The use of a formula for computing the approximate amount is very helpful A calculator has been devised for the estimation of the amounts of colloids and electrolytes on the basis of the size of the patient and the percentage of body surface burned [2] This calculator (Figs 104 and 105) might be very useful when one physician has to plan supportive therapy for a large number of burned patients

The main type of initial supportive therapy in a thermonuclear disaster would be carried out by supplying water and electrolytes for oral consumption A solution of salt and soda made by placing 3 gm of salt and 1 5 gm of sodium bicarbonate in a liter of water is a very effective solution for replacement therapy In order to provide such a solution, it might be possible to have salt soda and some type of water purification tablet placed in small packages to be given to patients for mixing with water [9] Such a solution is well tolerated by burned patients Any casualty with less than 30 per cent of the body surface burned could probably receive adequate temporary replacement therapy by the oral route Blood transfusions for the correction of anemia could be given several days later

Fig. 104



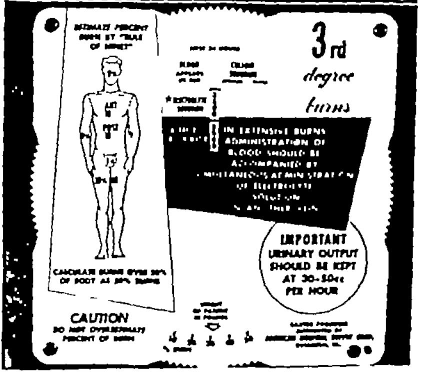


Fig. 105

FIG. 104 Fluid calculator for burns. The celluloid burn wheel offers a rapid method for estimating the amount of fluids required in a burned patient. In this photograph, the side for second degree burns is shown. The weight of the patient and per cent of burn are set in the scale at the lower part of the calculator The amount of colloid solution, electrolyte solution and water is shown in the open slots in the center of the upper portion of the calculator

FIG. 105 Side of fluid calculator to be used when burns are predominantly of the third degree variety Cautions concerning initial fluid therapy in burns are inserted on the calculator

Management of the Burn Wound

Under ideal circumstances cleansing of the burn with a mild soap or detergent is recommended but under disaster conditions this procedure would be impossible There is ample evidence that the lack of cleansing is a minor compromise, especially when burns are exposed In the event of a disaster, all burned areas would have to be treated by the exposure method because the few dressings available would have to be saved for mechanical injuries Should the disaster occur in a cold region, it would be necessary to furnish blankets and some type of covering for the injured surface If time permits and dressings are available they should be utilized on individuals who would benefit most by their use Some type of mittens would be desirable to use on burned hands. If flash burns occur on the hands and face, the burn casualty discharged to self care would be more effective if he had something to cover the wound of the hand

Antibiotics

Although burns of moderate size may be treated in a hospital without administering any antibiotics, it would seem wise to use antibiotics in a disaster situation The main reason for such prophylactic therapy is to prevent infections caused by beta hemolytic streptococcus. A broad spectrum antibiotic should be given orally for the first few days after injury At the time at which the casualty received the salt and soda solution, he could be provided with a sufficient supply of an oral antibiotic to last him for several days Regardless of the type of antibiotics used, the development of resistant bacterial strains and secondary infections could be expected. Provisions should be made for the utilization of additional antibiotics at a later date

BURN CENTERS

In any disaster, it is advisable to group similarly injured casualties in the same installation Certain hospitals should be designated as burn centers Among the supplies that should be available at the centers are blood, dressings, and high protein liquid feedings

One difficulty in dealing with a large number of burn casualties is sufficient space in an operating room and time to carry out the multiple grafting procedures that are necessary Another phase of sorting might be necessary within the burn center Casualties whose wounds could be closed by one grafting procedure should be taken into the operating room first so that they might return to duty

In grafting procedures, it is generally desirable to place large sheets of skin over flat surfaces. If there are a large number of casual

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